DOI: 10.29298/rmcf.v17i96.1673
Research article

Macromycetes of the *Chignahuapan-Zacatlán* region, State of *Puebla*, Mexico

Macromicetos de la región Chignahuapan-Zacatlán, Puebla, México

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Fecha de recepción/Reception date: 23 de marzo de 2026.
Fecha de aceptación/Acceptance date: 15 de junio de 2026.

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Abstract

In Mexico, around 6 500 taxa of macromycetes have been recorded; specifically in the state of *Puebla*, the number ranges between 97 and 131. This study documents the species identified in two sites in the *Chignahuapan-Zacatlán* region, whose forests are subject to forest management. Field sampling was conducted on 53 plots of 1 000 m^2 each, 30 in the *Rancho Nuevo Nanacamila ejido*, in *Zacatlán de las Manzanas* municipality, and 23 in the *Emiliano Zapata ejido*, in *Chignahuapan* municipality, *Puebla*; weekly field trips were conducted from July through November. A total of 114 species were identified, seven of which were classified in the division Ascomycota and 107 in Basidiomycota; there were 36 families and 56 genera. The order *Agaricales* was the best represented. Among the families, Russulaceae stood out with 20 species, followed by Amanitaceae with 13; the genera with the highest number of taxa were *Amanita* (13), *Russula* (12), and *Lactarius* (8). In terms of edibility, 59 species are listed as edible, and 15, as safe to eat with caution. A total of 34 species were identified that had not previously been recorded in the literature for the *Sierra Norte de Puebla*; this is significant, given the small area sampled (5.3 ha), which highlights the limited mycological exploration that has taken place in the region.

Keywords: Agaricales, *Amanita*, Basidiomycota, temperate forest, *Lactarius*, *Russula*.

Resumen

En México, se han registrado aproximadamente 6 500 taxones de macromicetos y específicamente para el estado de Puebla el número varía entre 97 y 131. En el presente estudio se documentan las especies identificadas en dos localidades de la región Chignahuapan-Zacatlán, cuyos bosques están sujetos a manejo forestal. Los muestreos de campo se hicieron en 53 parcelas de 1 000 m^2, 30 ubicadas en el ejido Rancho Nuevo Nanacamila, municipio Zacatlán de las Manzanas y 23 en el ejido Emiliano Zapata, municipio Chignahuapan, Puebla; los recorridos de campo fueron semanales durante los meses de julio-noviembre. Se reconocieron 114 especies, siete se agruparon en la división Ascomycota y 107 en Basidiomycota; con un total de 36 familias y 56 géneros. El orden Agaricales fue el mejor representado. En relación a las familias, destacaron Russulaceae con 20 especies, seguida por Amanitaceae con 13, cuyos géneros con mayor número de taxa fueron *Amanita* (13), *Russula* (12) y *Lactarius* (ocho). En cuanto a la comestibilidad, 59 especies son comestibles y 15 se citan de consumo con precaución. Se identificaron 34 especies sin registro previo en la literatura para la Sierra Norte de Puebla, lo cual es relevante dada la reducida superficie muestreada (5.3 ha) y evidencia la escasa exploración micológica existente en la región.

Palabras clave: Agaricales, *Amanita*, Basidiomycota, bosque templado, *Lactarius*, *Russula*.

Introduction

Mushrooms are one of the most diverse groups of organisms, with 2.2-3.8 million or, by a very conservative estimate, 1.5 million species (Hawksworth & Lücking, 2017). Approximately 200 000 of them are estimated to exist in Mexico (Guzmán, 1998); however, the understanding of fungal diversity is limited, as only around 6 500 taxa (3.5 %) have been recorded, most of which are macromycetes (Guzmán, 1998).

The Mexican states with the highest number of mycological records are *Veracruz*, *Jalisco*, the State of Mexico, *Sonora*, *Michoacán*, *Querétaro*, *Durango*, *Chihuahua*, *Tamaulipas*, *Morelos*, *Quintana Roo*, *Aguascalientes*, *Puebla*, *Campeche* and *Yucatán* (Aguirre-Acosta et al., 2014). In the case of *Puebla*, few studies have been carried out on mycological diversity; among them are those by Medel-Ortiz et al. (2011), who cite 97 species, while Aguirre-Acosta et al. (2014) record 181 taxa, although neither study mentions specific locations, while Pérez-López et al. (2015) document 25 taxa on *Cerro El Pinal*, in *Acajete* municipality, 19 of which are Basidiomycetes and six are Ascomycetes.

As for studies conducted in the *Sierra Norte*, Martínez-Alfaro et al. (1983) compiled an ethnomycological list of 84 species found in the *Cuetzalan* and *Zacapoaxtla* municipalities, in addition to those published by Vázquez-Mendoza and Valenzuela-Garza (2010), who described 130 species of wood-dwelling macromycetes; Vázquez-Mendoza (2012) conducted a review of herbarium specimens, identifying 131 taxa, 21 of which were medicinal; for their part, Vázquez et al. (2016) identified 95 species of lignicolous fungi. In a study conducted at the main market in *Zaragoza*, *Puebla*, Contreras-Cortés et al. (2018) identified 21 taxa of edible macromycetes.

Within this context, the objective of this study was to contribute to the understanding of fungi in *Puebla*, specifically those found in the *Sierra Norte*, by sampling sporomes during three rainy seasons in the *Rancho Nuevo Nanacamila ejido*, *Zacatlán de Las Manzanas* municipality (2015-2017), and *Emiliano Zapata ejido*, *Chignahuapan* municipality (2023-2025).

Materials and Methods

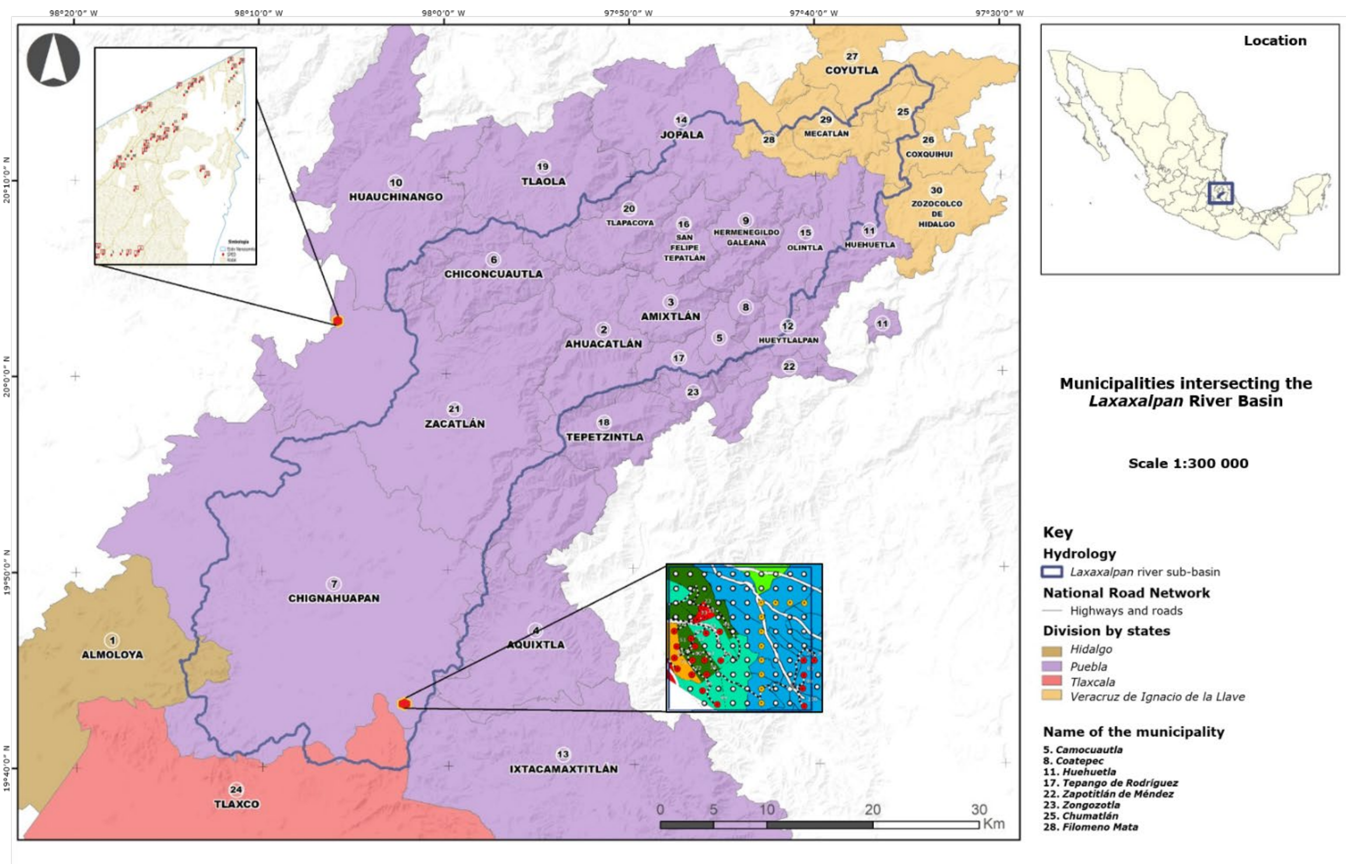
Study area

Sporomes were sampled from 53 sites, each 1 000 m^2 in size, located in two areas of the *Sierra Norte de Puebla* (Table 1; Figure 1): the *Rancho Nuevo Nanacamila ejido* (RN), in *Zacatlán de Las Manzanas* municipality (30), and the *Emiliano Zapata ejido* (EZ), in *Chignahuapan* municipality of (23). The total sampling area was 5.3 ha, and a quasi-systematic sampling design was used, with samples distributed across each of the silvicultural treatments applied in the *ejidos* (Table 1).

Table 1. Geographic and topographic characteristics and silvicultural practices at the sampling sites in the *Chignahuapan-Zacatlán* region, *Puebla*, Mexico.

Location	Coordinates (Degrees)	Alt. I. (m)	No. of sites	Sampling period
Rancho Nuevo Nanacamila ejido, *Zacatlán de las manzanas* municipality	20°02'54.24'' and 20°04'30.00'' N; 98°04'42.24'' and 98°06'38.88'' W	2 391-2 493	30 (RC=6; T1=7; T2=6; LC=11)	2015-2017
Emiliano Zapata ejido, *Chignahuapan* municipality	19°39'42" and 19°58'48" N; 97°57'18" and 98º18'06" W	2 757-2 855	18 (RC=3; LC, T2 and T3= 5 in each)	2023-2025
		2 877-2 919	5 (SL=5)	

Alt. I. = Altitude interval; RC = Regeneration cutting; LC = Cutting; T1 = Thinning 1; T2 = Thinning 2; T3 = Thinning 3; SL = Selective logging.



A = *Emiliano Zapata ejido*, *Chignahuapan*, *Puebla*; B = *Rancho Nuevo Nanacamila ejido*, *Zacatlán de Las Manzanas*, *Puebla*. Sampling sites = Red dots. *Huauchinango*

= *Huauchinango* municipality; *Tlaola* = *Tlaola* municipality; *Jopala* = *Jopala* municipality; *Coyutla* = *Coyutla* municipality; *Mecatlán* = *Mecatlán* locality; *Coxquihui* = *Coxquihui* locality; *Zozocolco de Hidalgo* = *Zozocolco de Hidalgo* locality; *Huehuetla* = *Huehuetla* municipality; *Olintla* = *Olintla* municipality; *Hermenegildo Galeana* = *Hermenegildo Galeana* municipality; *San Felipe Tepatlán* = *San Felipe Tepatlán* municipality; *Tlapacoya* = *Tlapacoya* municipality; *Chiconcuautla* = *Chiconcuautla* municipality; *Amixtlán* = *Amixtlán* municipality; *Ahuacatlán* = *Ahuacatlán* locality; *Hueytlalpan* = *Hueytlalpan* municipality; *Zacatlán* = *Zacatlán de las manzanas* municipality; *Tepetzintla* = *Tepetzintla* municipality; *Chignahuapan* = *Chignahuapan* municipality; *Aquixtla* = *Aquixtla* municipality; *Almoloya* = *Almoloya* locality; *Tlaxco* = *Tlaxco* municipality; *Ixtacamaxtitlán* = *Ixtacamaxtitlán* municipality.

Figure 1. Location of the sampling sites in two areas of the *Chignahuapan-Zacatlán* region, *Puebla*, Mexico.

***Rancho Nuevo Nanacamila ejido*.** The climate is classified as C(W"$_2$) (W) b(i), that is, a subhumid temperate climate with summer rainfall, an average temperature in the coldest month ranging from -3 °C to 18 °C, and an average temperature of up to 22 °C in the hottest month; annual precipitation ranges between 700 and 1 500 mm (Guizar-Nolasco et al., 2016). The forest is dominated by *Pinus patula* Schiede *ex* Schltdl. & Cham., with smaller stands of *P. teocote* Schiede *ex* Schltdl. & Cham., *P. leiophylla* Schiede *ex* Schltdl. & Cham., *P. rudis* Endl. (synonym of *Pinus hartwegii* Lindl.), *P. pseudostrobus* Lindl., *Abies religiosa* (Kunth) Schltdl. & Cham., *Quercus* spp., and *Arbutus xalapensis* Kunth (Zamora-Morales et al., 2018). Their physical characteristics contrast due to different silvicultural treatments applied as part of forest management based on the Silvicultural Development Method (SDM), which is applied to an area of 283.13 ha and involves regeneration cutting, cutting (parent trees) and thinning. The permanent monitoring sites were distributed across stands subject to the aforementioned harvests and covered an area of 33×33 m, with a distance of 100 m between sites within each stand.

***Emiliano Zapata ejido*.** The climate is temperate subhumid with summer rainfall (Cw) (García, 2004) and an average annual temperature of 13.4 °C. The vegetation consists of a pine forest dominated by *Pinus patula* and, to a lesser extent, *Pinus ayacahuite* Ehrenb. *ex* Schltdl.; *Abies religiosa* predominates in the higher elevations (2 919 masl), where selection cutting is carried out using the Mexican Method of Irregular Forest Management. The total area of the *ejido* under forest management is 249.65 ha, comprising 23 circular monitoring plots of 1 000 m^2 spaced 100 m apart within each stand.

Sporome collection and identification

Sampling was conducted weekly from July through November (the rainy season) during the years 2015-2017 (RN) and 2023-2025 (EZ). The fungal material was separated by species and stored in polyethylene bags or waxed paper; it was then mounted on herbarium sheets and identified by its macroscopic characteristics, using keys and texts with descriptions and images available in the specialized literature (Delgado-Fuentes et al., 2005; García-Rodríguez et al., 2012; Kong-Luz, 2003; Largent et al., 1986; Pérez-Moreno et al., 2009; Pérez-Silva & Herrera-Suárez, 1991; Phillips, 1991; Rodríguez-Alcalá et al., 2002). The taxonomic classification of the taxa is based on Cifuentes (2008) and *Index Fungorum* (2026). All specimens were deposited in the "*Biól. Luciano Vela Gálvez*" National Forest Herbarium (INIF) of the *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, INIFAP* (National Institute for Research on Forest, Agriculture and Livestock). Information on the uses of fungi was obtained from the sources cited in the bibliography (Contreras-Cortés et al., 2018; Dai et al., 2009; Hall et al., 2003; Montoya et al., 2007; Robles et al., 2007; Vázquez-Mendoza, 2012).

Results and Discussion

A total of 114 species were identified, seven of which belong to the Ascomycota division and 107 to Basidiomycota; they include five classes, 11 orders, 36 families, and 56 genera. The most well-represented family was Russulaceae, with 20 species, followed by Amanitaceae, with 13 (Table 2).

Table 2. Taxonomic classification of the species identified in the *Chignahuapan-Zacatlán* region, *Puebla*, Mexico.

Species	Habit	Uses	New register in the *Sierra Norte de Puebla*
ASCOMYCOTA			
Leotiomycetes			
Helotiales			
Leotiaceae			
Leotia lubrica (Scop.) Pers. (BP, RN)	ECM	E	
Pezizomycetes			
Pezizales			
Discinaceae			
Gyromitra infula (Schaeff.) Quél. (BP, EZ)	S	EC	
Helvellaceae			
Helvella crispa Bull. (BP, RN, EZ)	ECM	E	
H. lacunosa Afzel. (BP, RN, EZ)	ECM	E	
H. vespertina N. H. Nguyen & Vellinga (BP, EZ)	ECM	EC	XX
Pyronemataceae			
Otidea onotica (Pers.) Fuckel (BP, BA, RN, EZ)	S	E	XX
Sordariomycetes			
Hypocreales			
Hypocreaceae			
Hypomyces lactifluorum (Schwein.) Tul. & C. Tul. (BP, RN)	P	E	
BASIDIOMYCOTA			

Agaricomycetes			
Agaricales			
Agaricaceae			
Agaricus silvaticus Schaeff. (BP, BA, RN, EZ)	S	E	
A. silvicola (Vittad.) Peck (BP, BA, RN, EZ)	S	E	
A. subrutilescens (Kauffman) Hotson & D. E. Stuntz (BP, EZ)	S	E	XX
Lepiota clypeolaria (Bull.) P. Kumm. (BP, BA, EZ)	S	T	XX
L. cristata (Bolton) P. Kumm. (BP, EZ)	S	T	XX
L. magnispora Murrill (BP, EZ)	S	T	
Amanitaceae			
Amanita chlorinosma (Peck) Lloyd (BP, RN)	ECM	T	
A. gemmata (Fr.) Bertill. (BP, RN)	ECM	T	
A. grupo *caesarea* sensu Guzmán & Ramírez-Guillén (2001) (BP, RN)	ECM	E	
A. elongata Peck (BP, EZ)	ECM	T	XX
A. flavoconia G. F. Atk. (BP, RN, EZ)	ECM	E	XX
A. fulva Fr. (BP, BA, RN, EZ)	ECM	E	
A. muscaria (L.) Lam. (BP, RN, EZ)	ECM	T	
A. pachycolea D. E. Stuntz (BP, EZ)	ECM	E	
A. pantherina (DC.) Krombh. (BP, RN, EZ)	ECM	T	
A. rubescens Pers. (BP, BA, RN, EZ)	ECM	E	
A. vaginata (Bull.) Lam. (BP, BA, RN, EZ)	ECM	E	
A. verna Bull. *ex* Lam. (BP, EZ)	ECM	T	
A. xylinivolva Tulloss, Ovrebo & Halling (BP, EZ)	ECM	T	XX
Clitocybaceae			
Clitocybe fragrans (With.) P. Kumm. (BP, EZ)	ECM	T	XX
Crepidotaceae			
Crepidotus mollis (Schaeff.) Staude (BP, EZ)	S	NE	
Hydnangiaceae			
Laccaria amethystina Cooke (BP, BA, RN, EZ)	ECM	EC	XX
L. bicolor (Maire) P. D. Orton (BP, RN, EZ)	ECM	E	
L. laccata (Scop.) Cooke (BP, BA, RN, EZ)	ECM	E	
L. trichodermophora G.M. Muell. (BP, RN)	ECM	EC	XX
Hygrocybaceae			
Hygrocybe conica (Schaeff.) P. Kumm. (BP, EZ)	S	T	

Hygrophoraceae			
Ampulloclitocybe clavipes (Pers.) Redhead, Lutzoni, Moncalvo & Vilgalys (BP, BA, RN, EZ)	S	EC	XX
Hygrophorus chrysodon (Batsch) Fr. (BP, RN, EZ)	ECM	E	
H. russula (Schaeff. ex Fr.) Bataille (BP, BA, RN, EZ)	ECM	E	
Hymenogastraceae			
Gymnopilus penetrans (Fr.) Murrill (BP, BA, EZ)	S	T	
Incertae sedis			
Cystodermella cinnabarina (Alb. & Schwein.) Harmaja (BP, EZ)	S	NE	
C. granulosa (Batsch) Harmaja (BP, EZ)	S	NE	
Inocybaceae			
Pseudosperma sororium (Kauffman) Matheny & Esteve-Rav. (BP, BA, EZ)	ECM	T	
Lycoperdaceae			
Calvatia cyathiformis (Bosc) Morgan (BP, BA, EZ)	S	E	
Lycoperdon perlatum Pers. (BP, RN, EZ)	S	E	
Lycoperdon pyramidalis Timm (BP, RN, EZ)	S	E	XX
Lycoperdon umbrinum Pers. (BP, BA, RN, EZ)	S	EC	XX
Lyophyllaceae			
Lyophyllum decastes (Fr.) Singer (BP, RN)	S	E	
Mycenaceae			
Xeromphalina tenuipes (Schwein.) A. H. Sm. (BP, EZ)	S	NE	
Omphalotaceae			
Gymnopus dryophilus (Bull.) Murrill (BP, BA, RN, EZ)	S	E	
Rhodocollybia butyracea (Bull.) Lennox (BP, BA, EZ)	S	E	
R. lentinoides (Peck) Halling (BP, BA, EZ)	S	NE	
Pleurotaceae			
Pleurotus ostreatus (Jacq.) P. Kumm. (BP, EZ)	S	E	
Physalacriaceae			
Armillaria mellea (Vahl) P. Kumm. (BP, EZ)	S	E	
Oudemansiella canarii (Jungh.) Höhn. (BP, EZ)	S	E	
Strophariaceae			
Hebeloma fastibile (Pers.) P. Kumm. (BP, RN)	ECM	E	

Hypholoma fasciculare (Huds.) P. Kumm. (BP, BA, EZ)	S	T	
Leratiomyces squamosus (Pers.) Bridge & Spooner (BP, EZ)	S	T	
Tricholomataceae			
Infundibulicybe gibba (Pers.) Harmaja (BP, BA, RN, EZ)	S	E	
Leucopaxillus gentianeus (Quél.) Kotl. (BP, BA, EZ)	ECM	NE	
Tricholoma equestre (L.) P. Kumm. (BP, RN, EZ)	ECM	CP	XX
T. saponaceum (Fr.) P. Kumm. (BP, EZ)	ECM	EC	XX
Boletales			
Boletaceae			
Boletus aff. *edulis* Bull. (BP, RN)	ECM	E	
B. reticulatus Schaeff. (BP, RN)	ECM	EC	
B. rubriceps D. Arora & J. L. Frank (BP, EZ)	ECM	E	
B. subvelutipes Peck (BP, EZ)	ECM	E	
Butyriboletus regius (Krombh.) D. Arora & J. L. Frank (BP, RN)	ECM	EC	XX
Leccinum aurantiacum (Bull.) Gray (BP, RN, EZ)	ECM	EC	XX
Strobilomyces confusus Singer (BP, BA, EZ)	ECM	E	XX
Suillellus luridus (Schaeff.) Murrill (BP, EZ)	ECM	EC	XX
Xerocomellus chrysenteron (Bull.) Šutara (BP, BA, RN, EZ)	ECM	EC	XX
Hygrophoropsidaceae			
Hygrophoropsis aurantiaca (Wulfen) Maire *ex* Martin-Sans (BP, EZ)	S	E	
Sclerodermataceae			
Scleroderma areolatum Ehrenb. (BP, EZ)	ECM	T	
Suillaceae			
Suillus brevipes (Peck) Kuntze (BP, RN, EZ)	ECM	E	
S. granulatus (L.) Roussel (BP, RN, EZ)	ECM	E	
S. luteus (L.) Roussel (BP, RN)	ECM	E	
S. salmonicolor (Frost) Halling (BP, BA, RN, EZ)	ECM	EC	XX
Cantharellales			
Hydnaceae			
Cantharellus cinnabarinus (Schwein.) Schwein. (BP, BA, EZ)	ECM	E	

Cantharellus cibarius Fr. (BP, RN)	ECM	E	
Craterellus cornucopioides (L.) Pers. (BP, RN)	ECM	E	XX
Hydnum repandum L. (BP, RN)	ECM	E	
Clavulinaceae			
Clavulina cinerea (Bull.) J. Schröt. (BP, BA, RN, EZ)	ECM	E	
Clavulina coralloides (L.) J. Schröt. (BP, RN, EZ)	ECM	E	
Clavulina rugosa (Bull.) J. Schröt. (BP, BA, RN, EZ)	ECM	E	
Geastrales			
Geastraceae			
Geastrum saccatum Fr. (BP, BA, EZ)	S	NE	
G. triplex Jungh. [as 'Geaster'] (BP, EZ)	S	NE	
Gomphales			
Clavariadelphaceae			
Clavariadelphus truncatus Donk (BP, RN)	ECM	E	
Gomphaceae			
Phaeoclavulina myceliosa (Peck) Franchi & M. Marchetti (BP, EZ)	ECM	NE	XX
Ramaria aurea (Schaeff.) Quél. (BP, EZ)	ECM	EC	
R. aff *flava* (Schaeff.) Quél. (BP, BA, RN, EZ)	ECM	E	
R. stricta (Pers.) Quél. (BP, RN, EZ)	S	E	
Turbinellus floccosus (Schwein.) Earle *ex* Giachin & Castellano (BP, RN, EZ)	ECM	E	
Turbinellus kauffmanii (A. H. Sm.) Giachini (BP, EZ)	ECM	EC	
Polyporales			
Panaceae			
Panus conchatus (Bull.) Fr. (BP, EZ)	S	T	
Polyporaceae			
Neofavolus americanus J. H. Xing, J. L. Zhou & B. K. Cui (BP, EZ)	S	EC	
Sparassidaceae			
Sparassis crispa (Wulfen) Fr. (BP, EZ)	S	E	
Russulales			
Russulaceae			
Lactarius chrysorrheus Fr. (BP, RN, EZ)	ECM	E	XX
L. deliciosus (L.) Gray (BP, BA, RN, EZ)	ECM	E	
L. indigo (Schwein.) Fr. (BP, RN, EZ)	ECM	E	

L. deceptivus Peck (BP, RN)	ECM	T	XX
L. pubescens Fr. (BP, RN)	ECM	T	XX
L. aff. *salmonicolor* R. Heim & Leclair (BP, BA, RN, EZ)	ECM	E	
L. subdulcis (Pers.) Gray (BP, RN)	ECM	E	XX
L. vinaceorufescens A. H. Sm. (BP, EZ)	ECM	T	
Russula americana (Singer) Singer (BP, BA, EZ)	ECM	T	
R. brevipes Peck (BP, BA, RN, EZ)	ECM	E	
R. cerolens Shaffer (BP, EZ)	ECM	T	XX
R. claroflava Grove (BP, RN)	ECM	E	XX
R. delica Fr. (BP, BA, RN, EZ)	ECM	E	XX
R. emetica (Schaeff.) Pers. (BP, BA, RN, EZ)	ECM	EC	
R. mexicana Burl. (BP, RN, EZ)	ECM	EC	XX
R. olivacea (Schaeff.) Fr. (BP, BA, RN, EZ)	ECM	E	XX
R. queletii Fr. (BP, RN)	ECM	EC	XX
R. rhodocephala Bazzical., D. Mill. & Buyck (BP, EZ)	ECM	T	
R. sanguinaria (Schumach.) Rauschert (BP, EZ)	ECM	T	
R. xerampelina (Schaeff.) Fr. (BP, EZ)	ECM	E	
Telephorales			
Bankeraceae			
Sarcodon imbricatus (L.) P. Karst. (BP, RN)	ECM	E	XX

ECM = Ectomycorrhizal fungus; P = Parasite; S = Saprobe; E = Edible; EC = Edible with caution; NE = Non edible; T = Toxic; AF = *Abies* forest; PF = *Pinus* forest; EZ = *Emiliano Zapata ejido*; RN = *Rancho Nuevo Nanacamila ejido*. Based on Cifuentes (2008) and *Index Fungorum* (2026).

The taxonomic composition showed a marked dominance of the family Russulaceae, which accounted for 20 taxa, followed by the family Amanitaceae, with 13 identified species. Within the first group, the genus *Russula* had the greatest species diversity, with 12 species. This is consistent with the findings of García-Valencia et al. (2025), who, using genetic barcodes (ITS) to investigate the diversity of rhizosphere and ectomycorrhizal fungal communities (ECM) associated with roots in *Pinus* stands in the *Rancho Nuevo ejido*, identified *Russula* as one of the most prevalent taxa. These findings suggest that both genera are significant components of the local mycobiota, consistently with previous studies conducted in the *Sierra Norte de Puebla* that highlight, in particular, the presence of Amanitaceae (Pérez-López et al., 2015).

In terms of functional structure, ectomycorrhizal macrofungi accounted for 67.5 % of the identified taxa; this proportion corresponds to 33.6 % of the total reported for Mexico (Garibay-Orijel et al., 2020). Their high frequency is likely related to the abundance of potential hosts—*Pinus* and *Quercus* species—with which they form mutualistic relationships essential for the exchange of nutrients and carbon (Garibay-Orijel et al., 2020; Smith & Read, 2008). Saprobic fungi accounted for 31.5 % of the total recorded species, including various taxa widely distributed in temperate forest ecosystems (Table 2). The register of both functional groups is based on the type of study being documented, which was conducted by collecting sporomes-structures characteristic of both ectomycorrhizal macromycetes and saprobes.

Also identified was *Hypomyces lactifluorum* (Schwein.) Tul. & C. Tul., a parasitic taxon with high culinary value (González-Rivadeneira & Argueta-Villamar, 2018; Robles-García et al., 2018), whose hosts are edible mushrooms of the genera *Lactarius* and *Russula*, especially *R. brevipes s. l.* Peck.

The abundance of edible macrofungi found in the study areas (58 species) reflects their ethnomycological importance. A total of 371 species of edible fungi were recorded for Mexico (Garibay-Orijel & Ruan-Soto, 2014); thus, the identified taxa add up to 30.7 % of the total cited for the country. The genera *Amanita*, *Russula*, *Lactarius*, and *Suillus* accounted for the largest number of taxa (Table 2). It should be noted that both the genera *Amanita* and *Russula* have been reported to include a large number of edible species—50 in the former and 143 in the latter (Li et al., 2021; Zhang et al., 2015). In addition to the above, 15 species were identified that should be eaten with caution due to conflicting information regarding their consumption (Table 2).

Among the species of ethnomycological importance, the following stand out for their commercial significance, both nationally and internationally: *Amanita caesarea* complex Guzmán & Ramírez-Guillén (2001), *Boletus aff. edulis* Bull., *Lactarius* *deliciosus* (L.) Gray*, Cantharellus cibarius* Fr., *Turbinellus floccosus* (Schwein.) Earle *ex* Giachin & Castellano, and *Ramaria aff. flava* (Schaeff.) Quél. (Estrada-Martínez et al., 2009; Jiménez-Ruíz et al., 2013; Pérez-López et al., 2015). This highlights their potential as a resource that complements timber harvesting (Garibay-Orijel et al., 2009; Pérez-Moreno et al., 2009).

In addition, seven taxa reported to have medicinal properties were collected: *Lycoperdon perlatum* Pers. and *Leotia lubrica* (Scop.) Pers. (scarring), *Agaricus silvaticus* Schaeff. (antioxidant), *Infundibulicybe gibba* (Pers.) Harmaja (stimulant), and *Laccaria laccata* (Scope.) Cooke and *L. amethystina* Cooke and *Hydnum repandum* L. (antitumor) (Dai et al., 2009; Robles et al., 2007). Particularly, Vázquez-Mendoza (2012) identified 21 medicinal taxa from the *Sierra Norte de Puebla.* Worldwide, more than 500 species of wild fungi with medicinal properties are recognized, and approximately 100 of them are ectomycorrhizal (Pérez-Moreno et al., 2009, 2020).

Finally, seven taxa identified as toxic were recorded: *Amanita chlorinosma* (Peck) Lloyd, *A. flavoconia* G. F. Atk., *A. pantherina* (DC.) Krombh., *A. muscaria* (L.) Lam., *Lactarius pubescens* Fr., *L. deceptivus* Peck, and *Russula emetica* (Schaeff.) Pers. (Hall et al., 2003; Montoya et al., 2007). This finding takes on particular significance given the growing interest in harvesting and consuming wild mushrooms and highlights the importance of compiling detailed mycological inventories in regions where wild mushroom foraging is becoming increasingly common. This is to prevent poisoning cases that occur when a toxic species is mistaken for an edible one, mainly due to the ignorance and recklessness of inexperienced foragers, as well as to the loss of traditional mycological knowledge (Ruan-Soto, 2018; Yaneva et al., 2026).

In terms of species richness, 80 species have been documented in the state of *Puebla* (Guzmán, 2008; Marín-Castro et al., 2015; Pérez-López et al., 2015; Romero-Arenas et al., 2009; Vázquez et al., 2016; Vázquez-Mendoza & Valenzuela-Garza, 2010). Therefore, the taxa collected at the two sampled sites account for 87 % of the macromycetes recorded for the region, indicating a high level of species richness given the small sampling area (5.3 ha). Table 2 lists the species identified at each of the sites or at both.

A significant contribution of this study is the documentation of 34 species as new records for the *Sierra Norte de Puebla* (Table 2). Of these, 10 were collected only in the *Emiliano Zapata ejido* and nine in *Rancho Nuevo Nanacamila*. In both locations, most specimens were collected in pine forests, except for *Strobilomyces confusus* Singer and *Lepiota clypeolaria* (Bull.) P. Kumm., which were also collected in sacred fir forests; however, it is important to note that sampling was limited to five sites in this type of forest, which likely influenced the results. A similar pattern was observed for the total number of identified macromycetes, as 76 % were collected in the *Pinus* forest.

Regarding species numbers, the results indicate a similar proportion between the two study sites, with a slightly higher proportion in the *Emiliano Zapata ejido* (57 %) than in *Rancho Nuevo Nanacamila* (43 %) (Table 2). However, an ecological analysis calculating alpha and beta diversity is needed to supplement the information presented in this study.

Conclusions

This paper introduces fungi identified at two sites in the *Chignahuapan-Zacatlán* region of *Puebla*, where 114 species of macromycetes have been recorded; 34 of these represent new records for the *Sierra Norte de Puebla*. This is significant, given the small study area, and highlights the region's importance as a reservoir of fungal diversity associated with temperate forest ecosystems. Furthermore, there is a clear need to conduct a greater number of mycological surveys both in that region and throughout the rest of the state, especially considering the climate vulnerability and deforestation that affect the forests and the ecosystem services they provide.

There are 59 edible species recorded in the area, which highlights the potential of this non-timber forest resource as a source of protein for the diet of *ejido* members, as well as a source of additional income through its commercialization, thus incorporating this resource into forest management would contribute to the sustainable management of both timber harvesting and macromycete populations.

Acknowledgments

The authors would like to thank the communal landholders of *Rancho Nuevo Nanacamila* and *Emiliano Zapata* for their assistance in carrying out our field activities, as well as the *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias*, *INIFAP* (National Institute for Research on Forest, Agriculture and Livestock) for the funding provided through the projects: "Integrated forest resource management for the sustainability of ecosystem services in the face of climate change" ("*Manejo integrado de recursos forestales para la sustentabilidad de los servicios ecosistémicos ante el cambio climático*") and "Silvicultural treatments and their impact on populations of edible ectomycorrhizal fungi" ("*Los tratamientos silvícolas y su impacto en las poblaciones de los hongos ectomicorrizógenos comestibles*"), and Francisco Moreno Sánchez, MSc, for the creation of Figure 1.

Conflict of interest

Marisela Cristina Zamora-Martínez states that she did not participate in any stage of the document's editorial process.

Contributions by author

Marisela Cristina Zamora-Martínez: research design, data collection, supervision of fieldwork, identification of fungal material, drafting of the manuscript; Rocío Sánchez

Colín: fieldwork, identification of fungal material, systematization of field data; Fernando Ismael Chávez-Díaz: fieldwork, revision of the manuscript.

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