ACTA UNIVERSITARIA
Multidisciplinary Scientific Journal

| VOLUMEN 29 | 2019 |
ISSN online 2007-9621
http://doi.org/10.15174/au.2019.2127

Macromycetes of the San José educational park, municipality of Zinacantan, Chiapas, Mexico

Macromicetos del parque educativo San José, municipio de Zinacantán, Chiapas, México

Freddy Chanona-Gómez[1], Peggy Elizabeth Alvarez Gutiérrez[2]*, Yolanda del Carmen Pérez-Luna[3]
[1]Departamento de Vigilancia Sanitaria. Laboratorio Estatal de Salud Pública.
[2]Consejo Nacional de Ciencia y Tecnología (Conacyt)-Tecnológico Nacional de México-Instituto Tecnológico de Tuxtla Gutiérrez.
Carretera Panamericana km 1080 Col. Juan Crispín, 29050. Tuxtla Gutiérrez Chapas.
Correo electrónico: peggy.alvarez@hotmail.com; pealvarezgu@conacyt.mx
[3]Ingeniería Agroindustrial. Universidad Politécnica de Chiapas.
*Corresponding author.

Abstract

Chiapas is one of the most biodiverse regions of our Planet; however, the knowledge of tropical mushrooms in this state is limited. As a consequence of this lack of information of the mycobiota of Chiapas and areas such as San José (SJ) park, it is very important to carry out inventories of biotic resources as a basic and fundamental research tool for some protected areas, in order to develop studies for conservation. This study aims to prepare a list of the macrofungi species in the SJ park. Specimens were collected along five consecutive years, and 148 species (21 Ascomycetes and 126 Basidiomycetes) were identified. The most common substrate was humus (110 species, 74.82%). Forty-six species that can be used for human consumption were found. Thus, the mycological value for the study area was 31.29%. Also, 27 new records for Chiapas (5 Ascomycotina and 22 Basidiomycotina) were found.

Keywords: Macrofungal diversity; tropical mushrooms; mycological stock; ascomycotina; Basidiomycotina.

Resumen

Chiapas es una de las regiones más biodiversas del Planeta; sin embargo, el conocimiento de los hongos de las regiones tropicales es limitado, en particular, de la microbiota de Chiapas y en el parque educativo San José. Es muy importante llevar a cabo inventarios de los recursos bióticos como una investigación básica y es una herramienta fundamental para proteger las áreas en donde se desarrollen estudios de conservación. En este estudio, el objetivo fue hacer una lista de las especies de macromicetos del parque educativo San José. Los resultados muestran 148 especies identificadas (21 Ascomycetes y 126 Basidiomycetes). El sustrato más común fue el humus (110 especies, 74.82%). Se hallaron 46 especies que pueden ser utilizadas para consumo humano. Por tanto, el valor micológico del lugar fue de 31.29%. Adicionalmente, se encontraron 27 nuevos registros para Chiapas (5 Ascomycotina y 22 Basidiomycotina).

Palabras clave: Diversidad macrofúngica; hongos tropicales; inventario micológico; ascomycotina; basidiomycotina.

Recibido: 1 de noviembre de 2017 **Aceptado:** 11 de febrero de 2019 **Publicado:** 18 de septiembre de 2019

Como citar: Chanona-Gómez, F., Alvarez-Gutiérrez, P. E., & Pérez-Luna, Y. C. (2019). Macromycetes of the San José educational park, municipality of Zinacantan, Chiapas, Mexico. *Acta Universitaria 29*, e2127. doi. http://doi.org/10.15174.au.2019.2127

Introduction

Mexico is a mega-diverse country, and it is considered among the top five in the world in terms of species richness and endemism. Worldwide, it has a high diversity of flora and fauna and, therefore, one should expect to find also a great diversity of macromycetes; however, not enough studies exist of some regions of Mexico, in particular, in the state of Chiapas. This state has about 8000 species of vascular plants, whereas only about 440 species of fungi (Andrade-Gallegos & Sánchez-Vázquez, 2005) are known, out of the 20 000 estimated species (Chanona-Gómez, Andrade-Gallegos, Castellanos-Albores & Sánchez, 2007), representing only 2.2% of the estimated total. Recent research has found that most studies have been conducted in areas of the Lacandon Jungle, the Soconusco Coastal Plain, and Chiapas highlands in the municipalities of San Cristobal, Oxchuc, Zinacantan, and Chamula (Andrade-Gallegos & Sánchez-Vázquez, 2005). The San Jose (SJ) educational park is in the municipality of Zinacantan, Chiapas, with an altitude of 2350 MASL. Two species have been recently reported in this area, *Agaricus silvaticus* Schaeff and *Auriscalpium vulgare* (L.) Kuntze (Robles-Porras, Ishiki-Ishihara & Valenzuela, 2006). This study aims to create an inventory of the mycodiversity of San José educational park, in the municipality of Zinacantan, Chiapas.

Materials and Methods

Study area

It was located at the San Jose educational park, which is bordered on the north by the foothills of the natural protected area Huitepec (*Instituto de Historia Natural y Ecología* [IHN], 2004) and is located at 9 km southwest of the city of San Cristobal de las Casas, Chiapas (figure 1). Its predominant vegetation is the pine-oak forest and oak-pine, overhanging the following tree species: *Pinus ayacahuite*, *P. strobus*, *P. teocote*, *P. montezumae, P. oocarpa*, *Quercus oleoides*, *Q. lancifolia* and *Q. chartacea* (Álvarez-Espinoza, 2006). There is no permanent surface water on the site, and it is only temporarily crossed by the runoff of rainwater from the higher surrounding areas (IHN, 2004).

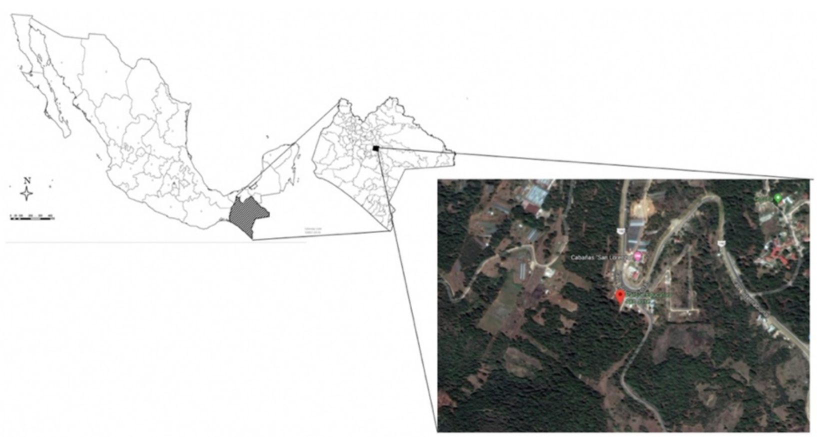

Figure 1. Localization of the San José educational park. Panamerican Road Km. 77.7, Tuxtla- San Cristobal s/n, 29200 Zinacantán, Chiapas.
Source: Author's own elaboration.

Sample collection and determination

The sample collection was performed on 12 mycological paths over the five years of the study, in order to explore and determine the macrofungal diversity of the studied area. Sampling was conducted through random walks crossing points throughout the area. This work consisted of listing the species collected in the SJ macromycetes park between the months of May and November, during the years 2009 to 2013. The collected specimens were identified according to their morphological characters with dichotomous keys and herborization. The macroscopic characteristics for determination were color, size, type of hymenium, presence/absence of volva, ring and other ornaments. The microscopic characteristics for determination were spore form and size. Data collection and data field recording were carried out according to Guzmán (1977) and screened for macromycetes growing on different substrates. Following the determination, the studied specimens were deposited in the Herbarium at the Institute of Natural History of the State of Chiapas. The identification was made using a macro and microscopic analysis based on the concept of morphospecies. In cuts for microscopic analysis of the fruiting body with spores, color changes were observed when adding 5% potassium hidroxide (KOH), methylene blue, and Congo red. Such determination was made using dichotomous keys and consulting specialized literature (Díaz-Barriga, 1992; Gilbertson, 1979; Gilbertson & Ryvarden, 1986; 1987; Guzman, 1977; 1979; Moser, 1978).

Results

A total of 380 specimens of macromycetes were collected at SJ park, and 148 species were determined (figure 2); twenty-one (14.28%) of them belong to Ascomycotina (table 1) and 126 (85.71%) to Basidiomycotina (table 2). Of the total specimens, 71.42% were determined as species and the rest as genus, due to the lack of identification keys in the specialized literature. Twenty-seven new specimens were recorded for Chiapas (table 3). Eighteen percent of the total new registrations correspond to Ascomycotina and 82% to Basidiomycotina. Seventy-eight new records for SJ park. The taxa with species more often found were Helvellaceae, with six species for Ascomycotina; while for Basidiomycotina, there were Amanitaceae (16 species, 10.88%), Tricholomataceae (15 species, 10.20%), Boletaceae (12 species, 8.16%) and Russulaceae (8 species, 5.4%).

Figure 2. Representative macrofungi found in PESJ. A. *Boletellus betula* Schewein; B. *Clitocybe clavipes* (Pers.:Fr) Kumm; C. *Crucibulum laeve* (Huds. Ex Relh) Kambly; D. *Tremella foliacea* Pers; E. *Craterellus cornucopioides* (L.) Pers; F. *Gyromitra infula* (Schaeff.) Quél; G. *Geoglossum fallax* E. J. Durand; H. *Amanita vaginata* (Bull.: Fr.) Vitt; I. *Cortinarius violaceus* (L.:Fr.) Gray; J. *Amanita vittadini* (Moretti) Vittadini.
Source: Author's own elaboration.

Table 1. List of Ascomycetes (Division *Ascomycota*, Class *Ascoycotina*) of the San Jose Park, Zinacantan, Chiapas.

Order	Family		Substrate	Importance
Heliotiales	Leotiaceae	*Leotia lubrica* Fries [SJ, Ch]	H	M; E; ME
		Leotia viscosa Fr.	H	M
Hypocreales	Cordycipitaceae	*Cordyceps capitata* (Hamski:Fr.) Link [SJ, Ch]	P	R
Pezizales	Geoglosaceae	*Geoglossum fallax* E. J. Durand [SJ, Ch]	H	NE
	Helvellaceae	*Helvella lacunosa* ex Fries [SJ]	H	M; E
		Helvella sp.	H	M
		Helvella crispa Scop.Fr.	H	M; E
		Macropodia macropus (Pers.) Fuckel [SJ]	H	S; E
		Paxina acetabulum (L. ex Amans) Kuntz [SJ, Ch]	H	S; E
		Gyromitra ínfula (Schaeff.) Quél [SJ]	H	M; E
	Humariaceae	*Aleuria aurantia* (Fr.) Fuck [SJ, Ch]	H	E
	Otideaceae	*Otidea alutacea* (Pers.) Massee	H	S; NE
		Otidea onotica (Pers.) Fuckel	H	S; NE
		Scutellinia scutellata (L.) Lambs [SJ]	L	S
	Pezizaceae	*Peziza hemisphaerica* Hoffm [SJ, Ch]	H	NE
		Peziza leucomelas (Pers.) Kuntze [SJ, Ch]	H	NE
		Peziza sp.	H	NE

ISSN online 2007-9621

	Sarcoscyphaceae	*Sarcosphaera eximia* (Durieu & Lév.) Maire [SJ, Ch]	L	S; D
		Sarcoscypha coccínea (Scop.:Fr.) Lamb [SJ, Ch]	H	NE
Xylariales	Xylariaceae	*Hypoxylon thouarsianum* (Lév.) Lloyd	L	S; NE
		Xylaria hypoxylon (L.:Fr.) Grev	L	S; NE

[SJ] New records for San José park
[Ch] New records for Chiapas
Substrate: H: humus; L: Lignicola;
Importance: S: Saprobe; M: Mycorrizic; P: Parasite; C: Edible; T: Toxic; NC: Non-edible; ME: Medicinal; R: Ritual; I: Insecticide; D: Dye; S: Special protection
Source: Author's own elaboration.

Table 2. List of Basidiomycetes (Division *Basidiomycota*, Class *Basidiomycotina*) of San Jose Park, Zinacantan, Chiapas.

Order	Family		Substrate	Importance
Agaricales	Agaricaceae	*Agaricus silvaticus* Schaeff Fr. [SJ]	H	M; C
		Chlorophyllum molybdites (G. Mey.: Fr.) Massee [SJ]	H	S; T
		Leucocoprinus fragilissimus (Ravenel ex Berk M.A. Curtis) Pat [SJ, Ch]	H	NC
		Macrolepiota procera (Scop.:Fr.): Singer [SJ]	H	C
	Amanitaceae	*Amanita caesarea* (Scop.: Fr.) Grev [SJ]	H	M; C; SPE
		Amanita codinae (Maire) Bertault [SJ, Ch]	H	M; T
		Amanita flavoconia G.K. Atk	H	M; T
		Amanita fulva (Schaeff.) Fr. [SJ]	H	M; C
		Amanita gemmata (Fr.) Bertill [SJ]	H	M; T
		Amanita hemibapha (Berk & Broome) Sacc [SJ, Ch]	H	M; T
		Amanita citrina (Schaeff) Pers. [SJ, Ch]	H	M; T
		Amanita perpasta Corner & Bas [SJ, Ch]	H	M
		Amanita muscaria (L.:Fr.) Lam	H	M; ME; I; T
		Amanita rubescens (Pers. Ex Fr.) Gray	H	M; C
		Amanita vaginata (Bull.: Fr.) Vitt	H	M; C
		Amanita sp. 1	H	M
		Amanita sp. 2	H	M
		Amanita pantherina (Dc.:Fr.) Krembt [SJ]	H	M; T
		Amanita virosa (Fr.) Bertault [SJ]	H	M; T; LRPV
		Amanita vittadini (Moretti) Vittadini [SJ, Ch]	H	M; C: LRPV
	Bolbitiaceae	*Conocybe* sp.	H	S
	Coprinaceae	*Coprinus* sp.	L	S
		Coprinus atramentarius (Bulliards.:Fries) Fries [SJ, Ch]	H	C; ME
		*Panaeolus semiovatus (*Sow.:Fr.) Lundell & Nannf [SJ]	E	S; T
		Psilocybe sp.	E	S; R; T
	Cortinariaceae	*Cortinarius* sp.	H	S
		Cortinarius violaceus (L.:Fr.) Gray [SJ]	H	C; TI
		Rozites caperatus [SJ, Ch]	H	S; C
		Inocybe sp. 1	H	M; T
		Inocybe sp. 2	H	M; T
	Crepidotaceae	*Crepidotus mollis* (Schaeff.) Staude	L	S
	Hygrophoraceae	*Hygrophorus* sp. 1	H	S
		Hygrophorus sp. 2	H	S
		Hygrophorus psittacinus (Schaeff.) Fr. [SJ, Ch]	H	S
	Lepiotaceae	*Lepiota* sp.	H	S
	Mycenaceae	*Mycena acicula* (Schaeff.) Kummer [SJ, Ch]	H	S
		Mycena sp.	H	S
	Strophariaceae	*Pholiota squarrosa (Vahl.) P. Kumm* [SJ, Ch]	L	S; T
		Hebeloma sp. [SJ]	H	S
		Hypholoma fasciculare (Fr.) [SJ, Ch]	L	S; T
		Naematoloma dispersum (Quél) P. Karst	H	S
		Naematolomma sp. 1	H	S
	Tricholomataceae	*Armillariella mellea* (Vahl.) P. umm [SJ]	P	C
		Clitocybe clavipes (Pers.:Fr.) Kumm [SJ, Ch]	H	S; C
		Clitocybe gibba (Pers.:Fr.) Kummer [SJ]	H	M; C; ME
		Clitocybe sp.	H	S
		Collybia alkalivirens Singer [SJ, Ch]	H	S
		Tricholoma equestre (L.) P. Kumm [SJ, Ch]	H	S; T

		Collybia dryophila (Bull.:Fr.) Murrill	H	C
		Collybia sp. 1	H	S
		Collybia sp. 2	H	S
		Laccaria amethistina (Bolton: Hook.) Murrill	H	M; C
		Laccaria laccata (Scop.:Fr.) Berk & Boome	H	M; C
		Lentinellus sp.	H	S
		Lyophyllum decastes (Fr.) Singer [SJ, Ch]	H	C
		Marasmius sp.	H	NC
		Omphalotus olearius (D.C.) [SJ, Ch]	P	T
	Psathyrellaceae	*Psathyrella* sp.	H	S
	Pterulaceae	*Ptreula* sp.	H	S
	Phallaceae	*Phallus impudicus* L.	H	M; C
		Phallus ravenelii Berk & M. A. Curtis [SJ, Ch]	H	M
	Schizophyllaceae	*Schizophyllum commune* Fr. [SJ]	L	S; C; ME
	Physalacriaceae	*Oudemansiella canarii* (Jungh.) Höhn [SJ]	L	S; C
Auriculariales	Auriculariaceae	*Auricularia auricula* (Bull.:Fr) Wettit [SJ]	L	C; S
Boletales	Boletaceae	*Austroboletus gracilis* (Corner) Wolfe	H	M
		Boletus griseus Frost [SJ]	H	M; LRPV
		Boletellus betula Schwein [SJ]	H	M; C
		Boletellus obscurococcineus (Höhn.) Singer [SJ, Ch]	H	M
		Boletus sp. 1	H	M
		Boletus sp. 2	H	M
		Boletus sp. 3	H	M
		Boletus sp. 4	H	M
		Porphyrellus porphyrosporus (Fr.) Gilbert [SJ, Ch]	H	M; LRPV
		Suillus tomentosus (Kauffman) Singer [SJ, Ch]	H	M
		Suillus sp.	H	M
		Xerocomus sp.	H	M
	Hygrophoropsidaceae	*Hygrophoropsis aurantiaca* (Wulfen) Maire [SJ, Ch]	H	C; S
Cantharellales	Cantharellaceae	*Craterellus cornucopioides* (L.) Pers. [SJ, Ch]	H	M; C
		Craterellus lutescens (Fr.) Fr. [SJ]	H	M; C
		Cantharellus cibarius Fr. [SJ]	H	M; C; SPE
		Cantharellus tubaeformis Fr.	H	C
	Clavariadelphaceae	*Clavariadelphus pistillaris* L. ex Fr. [SJ, Ch]	H	S; C
	Clavariaceae	*Clavaria vermicularis* Fries [SJ]	H	S
		Ramariopsis sp.	H	NC
	Hydnaceae	*Hydnum repandum* (L.) Fr.	H	M; C; ME
	Sparassidaceae	*Sparassis crispa* (Wulfen) Fr.	L; P	S; C; ME
Ganodermatales	Ganodermataceae	*Ganoderma lucidum* (Leyss ex Fr.) Karst [SJ]	L	S; ME; P
Gomphales	Ramariaceae	*Ramaria* sp. 1	CP	S
		Ramaria sp. 2	L	S
		Ramaria sp. 3	H	S
		Ramaria sp. 4	H	S
		Ramaria stricta (Pers.) Quél	H	M; C
Hericiales	Auriscalpiaceae	*Auriscalpium villipes* (Lloyd) Snell & EA Dick	CP	S
		Auriscalpium vulgare Gray	L	S; NC
		Clavicorona sp.	H	NC
Hymenochaetales	Hymenochaetaceae	*Phellinus* sp.	L	S
Lycoperdales	Geastraceae	*Geastrum triplex* Jungh [SJ]	H	M; ME
	Lycoperdaceae	*Lycoperdon perlatum* [SJ]	H	M
		Bovista sp.	H	NC
Nidulariales	Nidulariaceae	*Crucibulum laeve* (Huds. Ex Relh) Kambly [SJ, Ch]	L	S; NC
Thelephorales	Thelephoraceae	*Thelephora terrestris* Ehrenb [SJ, Ch]	H	S; NC
	Bankeraceae	*Phellodon niger* (Fr.) P. Karst	H	T
		Hydnellum peckii (Banker) Sacc [SJ, Ch]	H	M; LRPV
Poriales	Coriolaceae	*Fomes* sp.	L	S
		Perenniporia piophilia [SJ]	L	S
		Trametes versicolor (L.) Pil [SJ]	L	S; ME
	Lentinaceae	*Pleurotus djamor* (Rumphius:Fr.) Boed	L	S; C
	Polyporaceae	*Polyporus* sp. 1	L	S
		Polyporus sp. 2	L	S
		Polyporus sp. 3	L	S
		Meruliporia incrassata (Berk. & M.A. Curtis) Murrill [SJ, Ch]	L	S
		Favolus brasiliensis (Fr.) Fr. [SJ]	L	S
		Coltricia perennis (L:Fr.) Murr [SJ]	L	S; C
	Meruliaceae	*Steccherinum ochraceum* (Persoon.:Fries) S.F. Gray [SJ, Ch]	L	S
Russulales	Russulaceae	*Lactarius deliciosus* (Fries) S.F. Gray	H	M; C; ME

		Russula mexicana Burl.[SJ]	H	M; T
		Russula brevipes Peck	H	M; C
		Russula cyanoxantha (Schaeff ex Schwein) Fr [SJ]	H	M; C
		Russula heterophylla (Fr.:Fr.) Fr. [SJ, Ch]	H	M
		Russula subfoetens W. G. Smith [SJ]	H	M; T
		Russula sp. 1	H	M
		Russula sp. 2	H	M
Sclerodermatales	Sclerodermataceae	*Scleroderma areolatum* Ehrenb [SJ]	H	M; ME; T
Stereales	Stereaceae	*Stereum hirsutum* (Willdenow: Fries) S.F. Gray [SJ]	L	S; NC
Tremellales	Exidiaceae	*Exidia alba* (Lloyd) Burt [SJ, Ch]	H	S
		Tremella foliacea Pers.	L	S
		Tremella mesenterica Retz [SJ, Ch]	L	S; NC

[SJ] New records for San José park
[Ch] New records for Chiapas
Substrate: H: humus; L: Lignicola;
Importance: S: Saprobe; M: Mycorrizic; P: Parasite; C: Edible; T: Toxic; NC: Non-edible; ME: Medicinal; R: Ritual; I: Insecticide; D: Dye; S: Special protection
Source: Author's own elaboration.

Table 3. New records of macromycetes for Chiapas San José park, Zinacantan, Chiapas.

Order	Family	
Hypocreales	Cordycipitaceae	*Cordyceps capitata (Hamski.:Fr.) Link*
Pezizales	Helvellaceae	*Paxina acetabulum (L. ex Amans) Kuntz*
	Humariaceae	*Aleuria aurantia (Fr.) Fuck*
		Sarcosphaera eximia (Durieu & Lév) Maire
	Sarcoscyphaceae	*Sarcoscypha coccínea (Scop.:Fr.) Lamb*
Agaricales	Amanitaceae	*Amanita codinae (Maire) Bertault*
		Amanita hemibapha (Berk & Broome) Sacc
		Amanita citrina (Schaeff) Pers
		Amanita perpasta Corner & Bas
	Coprinaceae	*Coprinus atramentarius (Bulliards.:Fries) Fries*
	Cortinariaceae	*Rozites caperatus*
	Hygrophoraceae	*Hygrophorus psittacinus (Schaeff.) Fr.*
	Strophariaceae	*Pholiota squarrosa (Vahl.) P. Kumm*
	Tricholomataceae	*Clitocybe clavipes (Pers.:Fr) Kumm*
		Collybia alkalivirens Singer
		Lyophyllum decastes (Fr.) Singer
		Omphalotus olearius (D.C.)
	Phallaceae	*Phallus ravenelii Berk & M. A. Curtis*
Boletales	Boletaceae	*Boletellus obscurococcineus (Höhn.) Singer*
		Porphyrellus porphyrosporus (Fr.) Gilbert
	Hygrophoropsidaceae	*Hygrophoropsis aurantiaca (Wulfen) Maire*
Cantharellales	Cantharellaceae	*Craterellus cornucopioides (L.) Pers.*
	Clavariadelphaceae	*Clavariadelphus pistillaris L. ex Fr.*
Poriales	Meruliaceae	*Steccherinum ochraceum (Persoon.:Fries) S.F. Gray*
Russulales	Russulaceae	*Russula heterophylla (Fr.:Fr.) Fr.*
Tremellales	Exidiaceae	*Exidia alba (Lloyd) Burt*
		Tremella mesenterica Retz

Source: Authors' own elaboration.

Substrates

Macromycetes on humus (110 species) and on wood (32 species) were the most common. This is probably correlated with the type of vegetation, that is, pine-oak and oak-pine which constantly shed fascicles (pine needles) and broad leaves of *Quercus*, thereby, creating acid soil and high humidity which, along with the variety of microhabitat, produce the development of fungi on humus (Lodge & Cantrell, 1995). This is consistent with those reported by Guzmán-Dávalos & Guzmán (1979), who claim there are more lignicolous fungi in the tropics than in coniferous forests due to weather factors that promote the formation of humus.

Saprobes and ectomycorrhizal species

In addition, the results indicate that the group of saprobe fungi were the most common (68 species, 46.25%), followed by the ectomycorrhizal species (59 species, 40.13%). This is probably due to the fact that mycorrhizae develop in greater proportion in coniferous forests, compared to forests or rainforests, probably because weather conditions are generally not the most adequate; therefore, trees need to partner with other living organisms and other agents in order to properly absorb nutrients (Guzmán-Dávalos & Guzmán, 1979). Based on the results obtained, the families Amanitaceae (16 species, 10.88%), Tricholomataceae (15 species, 10.20%), and Boletaceae (12 species, 8.16%) were the most abundant within the group of mycorrhizae, which play a role in developing ecological forest populations and ecological succession, as well as in the promotion and alteration of the functions of niches (Kadowaki *et al.*, 2018). According to the findings by Garza, García & Castillo (1985), the genus Amanita is closely linked to productivity and the maintenance of a healthy forest. Some ectomycorrhizae, like *Amanita* and *Russula*, can use vegetable cellulose and polymers for degradation by joining broadleaf trees such as oaks, hence the importance of the study area where some species of *Quercus* sp. are dominant (Deacon, 1993).

The most common genera of ectomycorrhizal fungi observed were *Amanita, Boletus, Cantharellus, Clavariadelphus, Clitocybe, Gyromytra, Helvella, Inocybe, Laccaria, Lactarius, Ramaria, Russula, Scleroderma* and *Suillus*; therefore, it can be concluded that these taxonomic groups are abundant in *Quercus* forests (López-Eustaquio, Portugal, Bautista & Venegas, 2010; Pérez-Silva, Esqueda, Herrera & Coronado, 2006). Guzmán-Dávalos & Guzmán (1979) and Landeros, Castillo, Guzmán & Cifuentes (2006) also found abundant ectomicorrizogen species in these type of forests.

Edible fungi

A total of 43 (31.29%) edible species were found: *Agaricus silvaticus, Aleuria aurantia, Amanita vaginata, Amanita caesarea, Amanita fulva, Amanita rubescens, Amanita vittadini, Armillariella mellea, Auricularia auricula, Boletellus betula, Cantharellus cibarius, Cantharellus tubaeformis, Clavariadelphus pistillaris, Clitocybe clavipes, Clitocybe gibba, Collybia dryophilus, Coltricia perennis, Coprinus atramentarius, Cortinarius violaceus, Craterellus cornucopioides, Craterellus lutescens, Gyromitra infula, Helvella crispa, Helvella lacunose, Hydnum repandum, Hygrophoropsis aurantiaca, Laccaria amethystina, Laccaria laccata, Lactarius deliciosus, Leotia lubrica, Lyophyllum decastes, Macrolepiota procera, Macropodia macropus, Oudemansiella canarii, Paxina acetabulum, Phallus impudicus, Pleurotus djamor, Ramaria stricta, Rozites caperatus, Russula brevipes, Russula cyanoxantha, Schizophyllum commune* and *Sparassis crispa*. These species might be a sustainable food alternative for residents near the SJ park, as they could be used sustainably with biotechnological processes through cultivation; therefore, they can be considered as non-timber forest resources to contribute to the forest conservation and form a fundamental part of the structure and operation thereof, aiding in the capture of water, the conservation of diversity and as a source of income through alternative tourism or ecotourism (Pilz, Norvell, Danell & Molina, 2003).

Toxic fungi

Twenty-two (14.96%) taxa of toxic and hallucinogen fungi were found: *Amanita citrina, A. codinae, A. flavoconia, A. gemmata, A. hemibapha, A. muscaria, A. pantherina, A. virosa, Chlorophyllum molybdites, Hypholoma fasciculare, Inocybe* sp. 1, *Inocybe* sp. 2, *Omphalotus olearius, Panaeolus semiovatus,* *Phellodon niger, Pholiota squarrosa, Psilocybe* sp., *Russula mexicana, Russula subfoetens, Sarcosphaera eximia, Scleroderma areolatum and Tricholoma equestre.* The most abundant genera were Amanita; some of them may cause mycetism due to their toxicity (Díaz-Barriga, Guevara, Ferer & Valenzuela, 1988; Garza *et al*., 1985). *Chlorophyllum molybdites* and *Scleroderma areolatum* produce gastrointestinal mycetism, characterized by headache, fatigue, nausea, vomiting and diarrhea (Ott, Guzmán, Romano & Díaz, 1975). *Gyromitra esculenta*, although it is considered edible in some regions of Mexico, can have a neurotoxic effect (Carod-Artal, 2005*). Coprinus atramentarius* causes Coprinic syndrome, or disulfiram reaction (Pérez-Silva *et al*., 2006), while some species of *Amanita, Clitocybe* y *Omphalotus* contain muscarin and, therefore, may cause muscarinic syndrome. *Amanita muscaria* is one of the most toxic species known in Mexico, and it is considered toxic, hallucinogenic, medicinal and is even used as an insecticide. Some species of *Helvella* and *Gyromitra* can be eaten boiled, and the boiling water should be discarded, because they are toxic when consumed raw. According to Madrid (2005), *Schizophyllum commune* causes sinusitis, bronchopulmonary fungal infections, meningitis and lesions of the palate, although in Chiapas it is considered an edible mushroom. Only two fungi species (hallucinogens) growing on dung were found (1.36%), indicating that despite the fact of the area having moderate or latent disturbances, the incidence of free wild animals and/or livestock within the park is low. The zoo cages were not sampled due to security reasons. These results agree with Heredia (1989) at the Reserva El Cielo; both are protected areas. The ratio toxic: edible fungi was 1:2.3, which means that edible mushrooms are more abundant than toxic fungi.

Fungi with biotechnological and medical applications

Inside the SJ park, some fungi were found to have biotechnological and medical applications. *Cortinarius violaceus*, according to local knowledge, is a fungus used for the extraction of dyes which produce a stained purple-violet color. The dye can be extracted with a 70% ethanol solution. In Mexico, and specifically in Chiapas, some species are considered to have medicinal properties, such as: *Amanita muscaria*, *Clitocybe gibba*, *Coprinus atramentarius*, *Ganoderma lucidum*, *Geastrum triplex*, *Hydnum repandum*, *Lactarius deliciosus*, *Leotia lubrica*, *Schizophyllum commune*, *Scleroderma areolatum*, *Sparassis crispa* and *Trametes versicolor*. According to Ceballos *et al.* (2009), in México, *Amanita muscaria* and *Lactarius indigo* are used as purgatives; *Amanita caesarea* is used as an anti-inflammatory, and *Lactarius deliciosus* is used for asthma and intestinal pains. According to the results of this study, the mycological value of SJ park is higher than that of the Parque Educativo Laguna Bélgica, another park in Chiapas (Chanona-Gómez *et al*., 2007).

Discussion

In this study, and in former ones by the authors (Chanona-Gómez *et al*., 2007), it was observed that in the pine forests the soil is thinner and has less organic matter incorporated, compared with oak forest. The mulch in the oak forest is thicker and deeper, less acidic, and it has high levels of phosphorus, potassium and magnesium. This contributes to different nutrients' cycle of matter and energy, as well as to the diversity in ecotones, where both types of vegetation coexist. The amount of decomposed wood is lower than in other tropical zones; therefore, the species growing on wood tend to be less than those growing on humus. Deacon (1993) reports that some trees produce phenolic compounds that inhibit the growth of some species which are probably found in diverse proportion and abundance; so, the species that grow on decaying wood are highly specialized. The most abundant fungi that had grown on organic matter belong to the Polyporaceae family, while the Amanitaceae family was predominant for humus growing fungi (16 species, 10.88%).

Meanwhile, the saprobes and mycorrhizae fungi are important organisms for the ecological balance of the forest, because they decompose organic matter and degrade cellulose, hemicellulose, and lignin in ecosystems, and contribute to form the humus and the process of remineralization of the soil (Zamora-Martínez, 1999). However, saprobe fungi can cause economic loses for rational forest exploitation, because they reduce production levels and wood quality (López-Eustaquio *et al.*, 2010).

The results of the macrofungal diversity obtained may be due to the types of vegetation in the area, coverage, and/or tree density, successional forest condition, relative humidity, texture and soil compaction (due to humans and animals) as well as chemical composition and abundance of existing litter on the forest floor, which can be strongly influenced by environmental pollutants (Villanueva-Jiménez, Villegas-Ríos, Cifuentes-Blanco & León-Avedaño, 2006). According to Rydin, Diekmann & Hallingbäck (1997), the alteration of forest systems is based on the relation of the percentage of micorrizogenic species relative to the percentage of the total macromycetes. Based on this, it can be said that SJ park has an alteration or transformation known as *latent type*, because the percentage of the mycorrhizal fungi is higher than 40% and the lignicolous is less than 30%. This can be confirmed by observing the surrounding forest where the number of pedestrians, cars, buildings, crops and houses is growing by the day, which indicates a latent anthropogenic pressure and possible alteration of the environment.

Álvarez-Espinosa (2006) reported 80 species of macromycetes for SJ park, while the present research reports 148 species, 54.42% higher than those found in previous years. This may be due to several factors, such as seasonality of phenology and fructification of various species, relative humidity caused by the amount of rain and dew, effort (time and amount) of collection, which result in a significant loss of species identified and analyzed (Gazis, 2007; Lodge, 1997). Consequently, the results show fungal families that were never reported for SJ park before, such as Cortinariaceae and Hygrophoraceae, and new records for Chiapas and for the area. Thus, this study contributes significantly to the knowledge of the microbiota of SJ park and Chiapas.

According to Lodge (2001), *Agaricales* and *Polyporales* can adapt to changing conditions of temperature, humidity and rainfall through diverse dispersal strategies adapted to rain and wind, while *Coprinus, Hydnum, Lycoperdon* and *Marasmius* are primary colonizers in the process of succession, indicating that they are better suited to environments with moderate disturbance (Ortíz-Moreno, 2010). Also, the SJ park has successional linked to developmental processes, so that the mycorrhizal community can vary with the age of the trees and, therefore, the age of the forest. Both mycorrhizal fungal communities and saprobe fungi also exist in successional stages (Martínez-Peña 2008), so the number of species might increase the new collections made in the study site.

The study area is 15 ha, approximately, which corresponds to the 0.0198% of the Chiapas area, and this study has reported a total of 148 species, meaning a high fungal richness. Based on these results, and according to the Hawskorth index, it can be used to extrapolate the fungal diversity for the SJ park, so it is expected that area could have about 800 species of fungi, which means that it is still possible to find a greater number of species at the area. Thus, it is important to make new collections for longer periods, because the phenology of species is very variable. A greater effort of sampling, and a superior taxonomic study for identification are recommended. Currently, the area is protected by the Instituto de Historia Natural del Estado de Chiapas (Institute of Natural History of the State of Chiapas), and some studies have been conducted in Chiapas, like Álvarez-Gutiérrez, Chanona-Gómez & Pérez-Luna (2014), but the number of taxonomic and ecological studies is limited.

Most of the SJ park specimens studied are species that have been described in forests of pine, oak and conifers of Mexico (Pardavé-Díaz, Flores-Pardavé, Ruíz-Esparza & Castañeda-Romo, 2012). For example, *Schizophyllum commune* is very common in tropical areas (Guzmán, 1979), and it is used as an indicator of disturbance (Díaz-Barriga *et al.*, 1988), because it grows in sunny areas. Other common species of tropical zones were found, such as *Favolus brasiliensis*, *Ganoderma aplannatum*, *G. lucidum*, which usually develop in low densities in the forests of pine-oak forest transition to tropical rainforest (Guzmán-Dávalos & Guzmán, 1979). *Chlorophyllum molybdites* is a typical kind in paddocks of disturbed human areas and it was found near the limits of the park, which indicates that it is a latent disturbance area (Guzmán-Dávalos & Guzmán, 1979).

Studies conducted by López-Eustaquio *et al.* (2010), Guzmán (1979) and Guzmán-Dávalos & Guzmán (1979) reported that the characteristic species of pine-oak forests are *Amanita caesarea*, *A. muscaria*, *A. vaginata*, *Clitocybe claviceps*, *Hygrophoropsis aurantiaca*, *Laccaria laccata*, *Lactarius indigo*, *Lyophyllum decastes*, *Macropodia macropus*, *Naematoloma fasciculare*, *Suillus tomentossus* and *Omphalotus olearius*, which were found in SJ park. Also, *Agaricus silvicola*, *Clitocybe gibba*, *Laccaria laccata*, *Lactarius deliciosus*, *Porphyrellus porphyrosporus*, *Russula brevipes* and *Xeromphalina campanella* can be observed in pine-oak and fir forests.

A few species, such as *Amanita caesarea*, *A. hemibapha*, *A. muscaria* and *Cantharellus cibarius* are included in the category of *vulnerable*, according to the Official Mexican Standard NOM-059-ECOL-2001 (*Diario Oficial de la Federación* [DOF], 2002), while *Amanita virosa*, *Amanita vittadini*, *Boletus griseus*, *Hydnellum peckii* and *Porphyrellus porphyrosporus* are registered in the red list of the País Vasco (España) (Sociedad Pública de Gestión Ambiental, 2011).

Conclusion

Highlander regions of Chiapas have a wide biodiversity of macromycetes, in particular, conserved areas such as San José park at the municipality of Zinacantan, which according to the results of this study, the area has a wide micodiversity, with 148 species of macromycetes, 27 of them are new records for Chiapas.

Acknowledgements

This study was made possible thanks to the collaboration of the Institute of Natural History of Chiapas (*Instituto de Historia Natural de Chiapas*) and the authorities and park rangers of the SJ park. The authors wish to thank the students of the Faculty of Biology of the University of Science and Arts of Chiapas and the Agroindustrial Engineering Department of the Polytechnic University of Chiapas, in particular, Luis Ángel Hernández Díaz, Valentín Vázquez, Samuel Toledo and Dolores Luna Martínez, as well as many others.

References

Álvarez-Espinosa, O. (2006). *Diversidad y abundancia de macromicetos en el Parque Educativo San José Bocomtenelté, municipio de Zinacantán, Chiapas*. (Tesis de licenciatura). Universidad de Ciencias y Artes de Chiapas, Tuxtla Gutiérrez, Chiapas.

Álvarez-Gutiérrez, P. E., Chanona-Gómez, F., & Pérez-Luna, Y. C. (2014). *Hongos de Chiapas. Guía de campo.* Distrito Federal, México: Instituto Politécnico Nacional.

Andrade-Gallegos, R. H., & Sánchez-Vázquez, J. E. (2005). La diversidad de hongos en Chiapas: un reto pendiente. En: M. González-Espinosa, N. Ramírez-Marcial, & L. Ruiz-Montoya. (Coords.), *Diversidad Biológica en Chiapas* (pp. 33-80). Chiapas, México: El Colegio de la Frontera Sur, Consejo de Ciencia y Tecnología del Estado de Chiapas (Cocytech) y Plaza y Valdés.

Carod-Artal, F. J. (2005). Síndromes neurológicos asociados con el consumo de hongos y plantas alucinógenos. *Elementos revista de Ciencia y Cultura*, *60*(12), 49-57.

Ceballos, G., List, R., Garduño, G., López Cano, R., Muñozcano Quintanar, M. J., Collado, E., & San Román, J. E. (2009). *La diversidad biológica del estado de México. Estudio de estado*. Estado de México, México: Instituto de Ecología. Gobierno del Estado de México.

Chanona-Gómez, F., Andrade-Gallegos, R. H., Castellanos Albores, J., & Sánchez, J. E. (2007). Macromicetos del parque educativo Laguna Bélgica, municipio de Ocozocoautla de Espinosa, Chiapas, México. *Revista Mexicana de Biodiversidad 78*(2), 369-381.

Deacon, J. W. (1993). *Introducción a la micología moderna*. Chiapas, México: Limusa.

Diario Oficial de la Federación (DOF). (6 de marzo de 2002). Norma Oficial Mexicana NOM-059-ECOL-2001, *Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo*. Secretaría del Medio Ambiente y Recursos Naturales (Semarnat).

Díaz-Barriga, H. (1992). *Hongos comestibles y venenosos de la cuenca del lago de Pátzcuaro Michoacán*. Morelia, Michoacán, México: Instituto de Ecología.

Díaz-Barriga, H., Guevara-Fefer, F., & Valenzuela, R. (1988). Contribución al conocimiento de los macromicetos del estado de Michoacán. *Acta Botánica Mexicana*, *2*, 21- 44. doi: https://doi.org/10.21829/abm2.1988.564

Garza, F., García, J., & Castillo, J. (1985). Macromicetos asociados al bosque de *Quercus rysophylla* en algunas localidades del estado de Nuevo León. *Revista Mexicana de Micología 1*, 423-437.

Gazis, R. (2007). *Evaluation of the macrofungal community at los Amigos biological station, Madre de Dios, Perú* (Tesis de Maestría). Colegio de la Ciencia y la Tecnología. Universidad Cristiana de Texas, Texas, Estados Unidos de América.

Gilbertson, R. L. (1979). The genus *Phellinus* (Aphyllophorales: Hymenochaetaceae) in Western North America. *Mycotaxon*, *9*(1), 51-89.

Gilbertson, R. L., & Ryvarden, L. (1986). *North American polyporus*, vol. I.. Oslo: Fungi Flora.

Gilbertson, R. L., & Ryvarden, L. (1987). *North American polyporus*, vol. II. Oslo: Fungi Flora.

Guzmán-Dávalos, L., & Guzmán, G. (1979). Estudio ecológico comparativo entre los hongos (macromicetos) de los bosques tropicales y los de coníferas del sureste de México. *Boletín de la Sociedad Mexicana de Micología, 13*, 89-125.

Guzmán, G. (1977). Identificación de los hongos comestibles, venenosos, alucinantes y destructores de la madera. México: Limusa.

Guzmán, G. (1979). *Hongos*. México, D. F.: Limusa.

Heredia, G., (1989). Estudio de los hongos de la Reserva de la Biosfera El Cielo, Tamaulipas. Consideraciones sobre su distribución y ecología de algunas especies. *Acta Botánica Mexicana*, *7*, 1-18. doi: https://doi.org/10.21829/abm7.1989.577

Instituto de Historia Natural y Ecología (IHN). (2004). *Parque Educativo "San José" Bocomtenelté*. México: Instituto de Historia Natural y Ecología.

Kadowaki, K., Yamamoto, S., Sato, H., Tanable, A.S., Hidaka, A., Toju, H. Mycorrhizal fungi mediated the direction and strength of plant-soil feedbacks differently between arbuscular mycorrhizal and ectomycorrhizal communities. Communications Biology. 196, 1-11. doi: https://doi.org/10.1038/s42003-018-0201-9

Landeros, F., Castillo, J., Guzmán, G., & Cifuentes, J. (2006). Los hongos (macromicetos) conocidos en el cerro El Zamorano (Querétaro-Guanajuato). *Revista Mexicana de Micología, 22*, 25-31.

Lodge, D. J. (1997). Factors related to diversity of decomposer fungi in tropical forests. *Biodiversity & Conservation*, *6*(5), 681-688. doi: https://doi.org/10.1023/A:1018314219111

Lodge, J. (2001). Diversidad mundial y regional de hongos. In: H. M. Hernández, A. N. García Aldrete, F., Álvarez, & M. Ulloa (Comps.). *Enfoques contemporáneos para el estudio de la biodiversidad*. Distrito Federal, México: Ediciones Científicas Universitarias.

Lodge, D. J., & Cantrell, S. (1995). Fungal communities in wet tropical forests: Variation in time and space. *Canadian Journal of Botany, 73*(1), 1391-1398. doi: https://doi.org/10.1139/b95-402

López-Eustaquio, L., Portugal, D., Bautista, N., & Venegas, R. (2010). Biodiversidad fúngica de la reserva ecológica "Corredor biológico Chichinautzin", Morelos, México. In: D., Martínez-Carrera, N., Curvetto, M., Sobal, P., Morales, & V. M., Mora. (Eds.). *Hacia un desarrollo sostenible del sistema de producción-consumo de los hongos comestibles y medicinales en Latinoamérica: Avances y perspectivas en el siglo XXI*. Puebla, México: Red Latinoamericana de Hongos Comestibles y Medicinales, Producción, Desarrollo y Consumo-Colegio de Posgraduados.

Madrid, H. (2005). Notas sobre macromicetes de la zona central de Chile. *Boletín Micológico*, *20*, 29-33. doi: https://doi.org/10.22370/bolmicol.2005.20.0.267

Martínez-Peña, F. (2008). Producción de carpóforos de macromicetes epigeos en masas ordenadas de *Pinus sylvestris L*. (Tesis Doctoral). Universidad Politécnica de Madrid, Madrid, España

Moser, M. (1978). Keys to agarics and boleti (Polyporales, boletales, agaricales, Russulales). Tombridge: The White Friars.

Ortíz-Moreno, M. L. (2010). Macromicetos en zona rural de Villavicencio. *Orinoquia*, *14* (2), 125-132.

Ott, J., Guzmán, G., Romano, J., & Díaz, J. L. (1975). Nuevos datos sobre los supuestos licoperdáceos psicotrópicos y dos casos de intoxicación provocados por hongos del género *Scleroderma* en México. *Boletín de la Sociedad Mexicana de Micología, 9*, 67-76.

Pardavé-Díaz, L.M., Flores-Pardavé, L., Ruíz Esparza, V. F., & Castañeda Romo, R. C. (2012). Los agaricales del estado de Aguascalientes. *Investigación y Ciencia de la Universidad Autónoma de Aguascalientes*, *54*, 3-11.

Pérez-Silva, E., Esqueda Valle, M., Herrera, T., & Coronado, M. (2006). Nuevos registros de Agricales de Sonora, México. *Revista Mexicana de Biodiversidad*, *77*(1), 23-33.

Pilz, D. L., Norvell, L., Danell, E., & Molina, R. (2003). *Ecology and management of commercially harvested chanterelle mushrooms*. Oregon, EE.UU: United States Department of Agriculture (USDA). doi: https://doi.org/10.2737/PNW-GTR-576

Robles-Porras, L., Ishiki-Ishihara, M., & Valenzuela, R. (2006). Inventario preliminar de los macromicetos en los altos de Chiapas, México. *Polibotánica, 21*, 89-101.

Rydin, H., Diekmann, M., & Hallingbäck, T. (1997). Biological characteristics, habitat associations, and distribution of macrofungi in Sweden. *Conservation Biology*, *11*(3), 628-640. doi: https://doi.org/10.1046/j.1523-1739.1997.96437.x

Sociedad Pública de Gestión Ambiental. (2011). *Flora 07: Evaluación del grado de amenaza de los Macromicetos de la lista roja preliminar del País Vasco fase II*. Bilbao, España: Ihobe.

Villanueva-Jiménez, E., Villegas-Ríos, M., Cifuentes-Blanco, J., & León-Avendaño, H. (2006). Diversidad del género Amanita en dos áreas con diferente condición silvícola en Ixtlán de Juárez, Oaxaca, México. *Revista Mexicana de Biodiversidad*, *77*(1), 17-22.