Flora 229 (2017) 23–31

Contents lists available at ScienceDirect

Flora

journal homepage: www.elsevier.com/locate/flora

Taxonomic richness of lycophytes and ferns of the Mexican beech forest: Highest ever recorded among *Fagus* forests worldwide?

Marisol Gutiérrez-Lozano[a], Arturo Sánchez-González[a,*], Lauro López-Mata[b], Daniel Tejero-Díez[c]

[a] Laboratorio de Ecología de Poblaciones, Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo, Ciudad del Conocimiento, Carretera Pachuca-Tulancingo Km. 4.5, Mineral de la Reforma, Hidalgo, C.P. 42184, Mexico
[b] Colegio de Postgraduados, Posgrado en Botánica, Carretera México-Texcoco Km 36.5, Montecillo, Texcoco, Estado de México, C.P. 56230, Mexico
[c] Laboratorio de Botánica, Unidad de Morfología y Función, Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Avenida de Los Barrios 1/Los Reyes Iztacala/Tlalnepantla, Estado de México, C.P. 54090, Mexico

ARTICLE INFO

Article history:
Received 11 October 2016
Received in revised form 3 February 2017
Accepted 8 February 2017
Edited by Karsten Wesche
Available online 13 February 2017

Keywords:
Cloud forest
Disturbance
Species richness
Floristic similarity
Pteridophytes
Temperate forest

ABSTRACT

The composition, richness and distribution of fern and lycophyte species were studied in the three largest and most intact stands of the beech *Fagus grandifolia* subsp. *mexicana* in Mexico, located in the Sierra Madre Oriental (SMO) in the state of Hidalgo. During fieldwork, specimens were collected in these stands, and five 60 m^2 sampling plots were also selected in order to estimate the relative importance value (RIV) of the species at each locality. Floristic similarity between localities was calculated based on species absence/presence data, and richness was estimated as a measure of plant biodiversity. In both analyses, data from previous studies in different regions of the SMO were included. In total, 21 families, 49 genera and 82 species of ferns and lycophytes were recorded for the beech forest of the state of Hidalgo; five of those species fall under a risk category according to Mexican legislation. Most species had either terrestrial or epiphytic habit. The species with high RIV differed among localities, except for *Lophosoria quadripinnata* which was dominant at all three localities. Our results indicate that Mexican *Fagus* forests have a higher richness of lycophyte and fern species per unit area than any other *Fagus*-dominated forests in the world. Thus, conservation and management programs should be implemented in the short term, in view of the limited area occupied by these forests and the constantly increasing levels of human-generated disturbance.

1. Introduction

The *Fagus* (*sensu* Rzedowski, 2006) or beech forest, whose canopy is dominated by *Fagus grandifolia* Ehrh. subsp. *mexicana* (Martínez) E. Murray (Valencia and Flores-Franco, 2006), represents a plant association of special interest in the context of the Mexican cloud forest (MCF), since it is a relic of the Pliocene–Miocene. Its current distribution is restricted to the mountainous regions of the Sierra Madre Oriental in the Mexican states of Hidalgo, Puebla, San Luis Potosí, Tamaulipas and Veracruz (Rowden et al., 2004; Williams-Linera et al., 2003). Unlike other temperate *Fagus* forests of the Americas, Asia or Europe, the Mexican beech forests are subtropical and represent the southern distribution limit of this forest at a latitude of 21°N (Peters, 1995; Ortiz-Quijano et al., 2016).

The *Fagus* forest in the state of Hidalgo covers an area of 106.79 ha, which represents 73% of the known extent of this plant community in the entire country, making it the largest beech forest in Mexico and also the least disturbed (Williams-Linera et al., 2003; Rowden et al., 2004; Rodriguez-Ramirez et al., 2013). Since the forest grows in a narrow elevation band where mist forms, it is highly vulnerable to both climate change and human-caused disturbances (Ortiz-Quijano et al., 2015). In general, ca. 60% of the area presently occupied by the cloud forest (CF) of the state of Hidalgo is disturbed, because of land use change to crop agriculture and cattle ranching, and by logging and habitat fragmentation. These result in changes to the species composition and structure of the forest, the

* Corresponding author.
E-mail addresses: arturosg@uaeh.edu.mx, artsag@hotmail.com (A. Sánchez-González).

http://dx.doi.org/10.1016/j.flora.2017.02.008
0367-2530/

magnitude of which depends on the frequency, intensity and size of the disturbance (Ortiz-Quijano et al., 2015; Vargas-Rodríguez et al., 2010).

Knowledge of the identity and biology of plant species coexisting in the *Fagus* forest in Mexico has increased in recent years as a result of several ecological and floristic studies on non-vascular plants (Mejía, 2015) and vascular flowering plants (Alcántara and Luna-Vega, 2001; Chávez, 2014; Ortiz-Quijano et al., 2016; Williams-Linera et al., 2003). Additionally, several studies have contributed quantitative data on the demography and population structure of *Fagus grandifolia* subsp. *mexicana* (Godínez-Ibarra et al., 2007; Ortiz-Quijano et al., 2016). However, the available information on lycophyte and fern species growing in the beech forests of Mexico is limited, although both groups are important structural components of the Mexican cloud forest and actively participate in the regeneration of disturbed sites (Tejero-Díez et al., 2014). Unlike many vascular plants with seeds, lycophytes and ferns require particular environmental conditions—especially high atmospheric humidity—for reproduction and proper physiological functioning (Arcand and Ranker, 2008), which is why they usually serve as indicators of climate conditions (Arcand and Ranker, 2008; Mehltreter, 2008; Mehltreter, 2010; Paciencia and Prado, 2005).

The present study aims to: (1) assess the composition, structure and distribution of lycophyte and fern species in the least disturbed patches of *Fagus grandifolia* subsp. *mexicana* forest in Mexico, and (2) based on species richness and composition, assess whether the patches of this forest represent an oasis or refuge for ferns and lycophytes, given that they are among the cloud forest sites in Mexico with the lowest degree of disturbance, and have relatively homogeneous environmental conditions. The small total area of beech forest in Mexico (less than 150 ha), along with the continuously increasing stress on it because of human activities, justify the effort to conduct floristic and ecological studies to characterize it in detail and to propose appropriate short term management and conservation programs or strategies. Moreover, we contribute to ongoing studies on diversity and ecology of lycopods and ferns in beech forests around the world. Regional data will enable comparative analyses of differences and similarities between these forests on a supra-regional scale.

2. Materials and methods

2.1. Area of study

The patches of *Fagus* forest studied in this work are distributed in the municipalities (county equivalents) of San Bartolo Tutotepec, Tenango de Doria and Zacualtipán de Ángeles in the eastern part of the state of Hidalgo, on windward slopes of the Sierra Madre Oriental (Table 1, Fig. 1). This forest grows at an elevation from 1560 to 1987 m, in sites with irregular topography, on slopes of 20° to 42° (Rodríguez-Ramírez et al., 2013). The soils are of ando (originating from volcanic ash), humic and vitric types, following the FAO-UNESCO classification, with a clay loam texture and an acid pH between 4 and 6 (Peters, 1995; Rodríguez-Ramírez et al., 2013). The climate is humid temperate (Cm(f)b), with an annual mean temperature of 12.7 °C and an annual minimum temperature of −10 °C; the summers are long and cool; the precipitation and mist regime is constant throughout the year; and annual cumulative precipitation is 1500 to 2300 mm. Average annual atmospheric humidity ranges between 60 and 85% (García, 1988 Peters, 1995).

The forest canopy is dominated by *Fagus grandifolia* subsp. *mexicana* (Fagaceae); other tree species characteristic of this association are *Quercus corrugata* Hook, *Q. delgadoana* S. Valencia, Nixon & L. M. Kelly, *Q. xalapensis* Humb. & Bonpl., *Clethra macrophylla* M. Martens & Galeotti, *Liquidambar macrophylla* Oerst., *Magnolia schiedeana* Schltdl. and *Podocarpus reichei* J. Buchholz & N.E. Gray (Ortiz-Quijano et al., 2016; Villavicencio-Nieto and Pérez-Escandón, 2008; Williams-Linera et al., 2003). Numerous shrubs and herbaceous plant species grow in the understory. The most important species include *Begonia incarnata* Link & Otto, *Cestrum fasciculatum* (Schltdl.) Miers, *Deppea purpusii* Standl., *Epifagus virginiana* (L.) W.P.C. Barton, *Eugenia capuli* (Schltdl. & Cham.) Hook. & Arn., *Miconia glaberrima* (Schltdl.) Naudin and *Rubus pringlei* Rydb. (Chávez, 2014; Godínez-Ibarra et al., 2007).

2.2. Field work

Between December 2011 and May 2014, the municipalities and localities with beech forest in the state of Hidalgo were explored and specimens were collected (Table 1). Lycophytes and ferns were sampled in rectangular plots being 60 m^2 in size (3 × 20 m) in order to determine the population variables of coverage and density for each species, so as to assess their structural importance (Franco et al., 2001). Five sampling plots at least 20 linear m apart were selected per locality (15 plots in total). This plot size and distribution has been recommended in other studies for sampling the herbaceous layer in plant communities in temperate climates (Franco et al., 2001; Mueller-Dombois and Ellenberg, 1974).

2.3. Laboratory work

The collected lycophyte and fern specimens were identified mainly according to the work of Mickel and Smith (2004) and they were deposited at the HGOM herbarium (Centro de Investigaciones Biológicas) of the Universidad Autónoma del Estado de Hidalgo; 46 duplicates were deposited in the Herbario Nacional (MEXU) at the Instituto de Biología of the Universidad Nacional Autónoma de México.

Using incidence data, the species inventory completeness percentage was calculated by means of two conventional non-parametric species richness estimator; first-order jackknife, and bootstrap (Colwell and Coddington, 1994). EstimateS v. 9.1.0 software (Colwell, 2015) was used for the analysis.

Using the relative values of the structural variables for cover and density, the relative importance value (RIV) of the species was estimated, modified from the RIV proposed by Mueller-Dombois and Ellenberg (1974). Density was defined as the total number of individuals of each species per unit area, and cover (C) was calculated using the formula: $C = \pi * (d_1/2) * (d_2/2)$, where $\pi = 3.1416$, d_1 and d_2 are the major and minor diameters perpendicular to each other of the vertical projection of the crown of the individual; and RIV = (relative coverage + relative density)/2.

In order to compare the degree of similarity in species composition among the *Fagus* forest localities in the state of Hidalgo, and to compare these to other localities with cloud forest in Mexico (Cartujano et al., 2002; Pérez-Paredes et al., 2012; Vázquez et al., 2006; Williams-Linera et al., 2004), a cluster analysis was carried out. The Jaccard index was chosen as the distance measure for determining the similarity among groups and the group average was used as a linking method (McCune and Grace, 2002). The PC-ORD program (McCune and Mefford, 1999) was used for the analysis.

As a complement, the species richness of the *Fagus* forest was compared with the species richness measured in other studies of lycophytes and ferns in different types of vegetation and other states of Mexico, using the taxonomic biodiversity index (BI): BI = S/Ln A, where S = total of recorded species and lnA = natural logarithm of the size of the area (Squeo et al., 1998).