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RICHNESS AND CURRENT STATUS OF GYMNOSPERM COMMUNITIES IN AGUASCALIENTES, MEXICO

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ABSTRACT

The gymnosperm diversity of Aguascalientes, Mexico, is presented. Fifteen species from five genera and three families are reported, two of Coniferales (Cupressaceae and Pinaceae) and one of Gnetales (Ephedraceae). *Pinus* is the most diverse and abundant genus with seven species. The most abundant species is *P. teocote*, while *P. strobiformis* is the scarcest. *Juniperus* is the next most diverse genus, represented by four species, with *J. deppeana* the most abundant and *J. durangensis* the scarcest. *Cupressus lusitanica*, *Taxodium mucronatum* and *Ephedra compacta* are each the sole representatives of their genera. Most conifers occupy the mountainous part of the state, forming temperate forest; exceptions are *Taxodium*, which is located on the margins of permanent streams, and *J. coahuilensis*, which is found in the low parts of the Aguascalientes Valley over calcareous soils in the northern part of the state. *Ephedra* is distributed in the northeast part of Aguascalientes in microphyll desert scrub. The current status of the gymnosperm communities in the state of Aguascalientes is discussed.

Key words: Aguascalientes, conifers, *Ephedra*, Mexico, temperate forest.

INTRODUCTION

According to the most recent molecular data, gymnosperms are a natural group that includes four extant main lineages: cycads as the most divergent group, followed by ginkgos and then conifers plus gnetophytes (Bowe et al. 2000; Chaw et al. 2000; Chase and Reveal 2009; Lu et al. 2014). Gymnosperms are distributed worldwide, the majority in temperate regions, although there are several species adapted to dry environments such as *Ephedra* and *Welwitschia*, or to tropical environments such as cycads and *Gnetum*. Even though Mexico is a megadiverse country (CONABIO 1998), gymnosperms make up only about 2% of its flora (Contreras-Medina et al. 2007). However, it has the world's second richest diversity in cycads and is an important center of diversity and endemism worldwide (Farjon and Styles 1997). Several treatments of Mexican gymnosperm diversity have been published (Martínez 1948, 1963; Carvajal and McVaugh 1992; Espinosa-Garduño 2001; García-Arévalo and González-Elizondo 2003; Del Castillo et al. 2004; Germandt and Pérez de la Rosa 2014). Nevertheless, there are some Mexican states where gymnosperm diversity has been little explored, including Aguascalientes, which presents an interesting gymnosperm species distribution in spite of its arid landscape.

Aguascalientes is one of the smallest states of Mexico, which has enabled considerable progress in the study of its flora, especially as regards gymnosperms and dicots. Of the total flora of Aguascalientes, so far we have studied 142 of the 180 families that have been estimated for an updated floristic checklist of the State of Aguascalientes (Gerardo García-Regalado, Margarita

De la Cerda-Lemus, Julio Ramírez-Martínez and María Elena Siqueiros-Delgado, in prep.), including the three gymnosperm families found in Aguascalientes (Cupressaceae, Ephedraceae and Pinaceae). Given the topography and climatic characteristics of Aguascalientes, gymnosperm diversity is moderate. However, in the mountainous area we can find conifer forests (*Cupressus lusitanica*, *Juniperus* spp. and *Pinus* spp.), scarce gallery forests (*Taxodium mucronatum*) along dry stream beds elsewhere in Aguascalientes, or as elements of xerophytic shrub (*Ephedra compacta*) in a small region in the northeast (Fig. 1–5). The highest percentage of gymnosperm species in Aguascalientes is located in the west of the state in a massif that has a north to south orientation and links a series of low hills and plateau systems, collectively called “Sierra Fría” in the north and “Sierra del Laurel” in the south (Fig. 6). Pine forests are common in the highlands, juniper forests in the plains, and cypress forests in the valleys, usually associated with oaks. Pure forests of pine, juniper or cypress are extremely scarce in Aguascalientes, covering an area of only 0.71% of the total area of natural vegetation (Siqueiros et al. 2016). However, the temperate region covered by mixed forest (oak-pine-juniper or oak-cypress), manzanita scrub [*Arctostaphylos pungens* Kunth] and temperate grasslands constitutes 30.48% of the natural Aguascalientes vegetation (Siqueiros et al. 2016). *Ephedra compacta*, on the other hand, occupies a smaller area in the northeastern part of Aguascalientes dominated by microphyll desert scrub, which is an extension of the Chihuahuan desert.

In recent years, significant progress has been made in the study of the Aguascalientes flora, and the study of the gymnosperm flora is now complete. Noteworthy among the publications on gymnosperm biodiversity in the state are Martínez (1948), Rzedowski and McVaugh (1966), Sánchez-Durón et al. (1967), Bolio et al. (1970), Pérez de la Rosa (1985), García et al. (1999) and Siqueiros (1999). The most comprehensive works are those of Siqueiros (1999) and García et al. (1999) who reported 10 species of gymnosperms from Aguascalientes.



Fig. 1–5. Gymnosperm communities in Aguascalientes, Mexico.—1. *Ephedra compacta* habitat in Tepezalá.—2. *Juniperus* forest at Laguna Seca, San José de Gracia.—3. *Cypripedium* at Barranca los Planes, San José de Gracia.—4. *Taxodium* at Arroyo la Gloria, Jesús María.—5. Pine forest at Barranca el Rico, San José de Gracia.

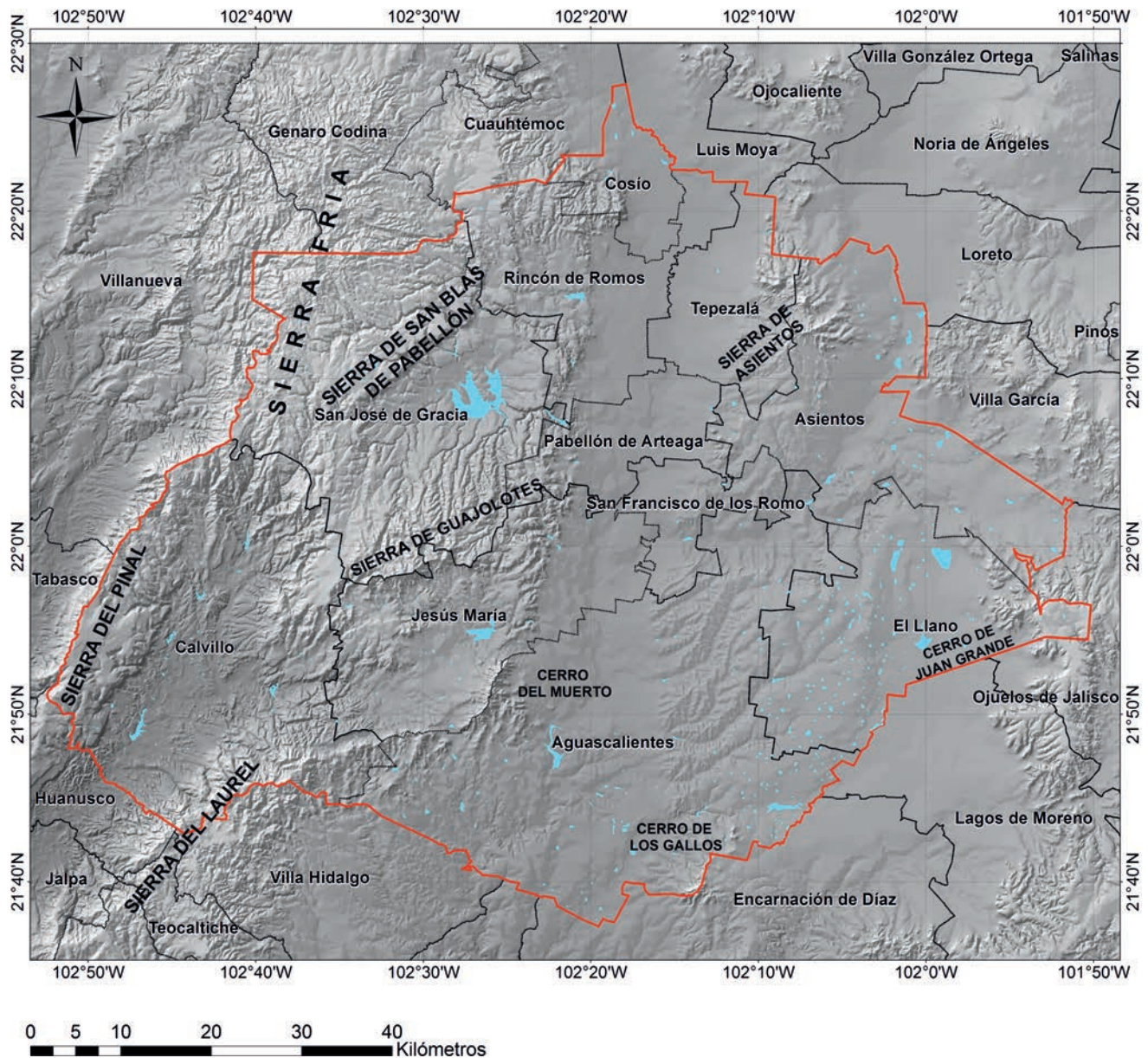


Fig. 6. Map of municipalities and the main topographical features of Aguascalientes, Mexico.

This paper aims to present the complete and updated floristic list of gymnosperm species distributed in Aguascalientes and to provide some information about the current situation of their communities.

STUDY AREA

Aguascalientes is one of the smallest states of Mexico with 5680 km², representing approximately 0.3% of the national area. It is located between 21°38'03" and 22°27'06" northern latitude and 101°53'09" and 103°00'51" western longitude and elevations range from 1500 to 3050 m (INEGI 1981). It is bordered by Zacatecas to the north, east and west, and by Jalisco to the south, and includes eleven municipalities (Aguascalientes, Asientos, Calvillo, Cosío, El Llano, Jesús María, Pabellón de Arteaga, Rincón de Romos, San Francisco de los Romo, San José de

Gracia and Tepezalá; Fig. 6). Most of the state is occupied by a central plateau which corresponds to the physiographic region named "Mesa del Centro." It has a north to south orientation, extending eastward with a few isolated ranges, such as the "Sierra de Los Gallos," "Sierra de Tepezalá" and "Sierra de la Comanja" (Rodríguez-Ávalos 2014). This region is covered mainly by xerophytic scrub with *Acacia schaffneri* (S. Watson) F.J. Herm., *A. farnesiana* (L.) Willd., *Prosopis laevigata* (Humb. & Bonpl.) M.C. Johnst., or *Mimosa monancistra* Benth. Microphyll scrub is found in the eastern region, adjacent to Zacatecas, as a southern extension of the Chihuahuan Desert (Granados-Sánchez et al. 2011), with species such as *Ephedra compacta*, *Calliandra eriophylla* Benth., *Condalia warnockii* M.C. Johnst., *Mortonia palmeri* Hemsl., and a very restricted population of *Larrea tridentata* (DC.) Coville, among others. This zone occupies only 10.7% of the total xeric scrub of the state, and it is located in the

municipalities of Asientos and Tepezalá. The mountainous region of Aguascalientes is located in the northwest in the foothills of the Sierra Madre Occidental. It exhibits a north-south orientation and mainly holds oak and conifer forests with elevations exceeding 3000 m. It encompasses the municipalities of San José de Gracia, Calvillo, Jesús María, Rincón de Romos and Pabellón de Arteaga and consists of several mountain ranges and plateau systems, separated by deep ravines and small intermountain valleys. Although they are collectively called “Sierra Fría”, actually the Sierra Fría is the northernmost mountain range, which continues northward into Zacatecas. The Sierra de San Blas de Pabellón, Sierra de Palomas, Sierra de Guajolotes, Sierra del Pinal and, to the southeast, Sierra del Laurel are the more prominent ridges in Aguascalientes.

According to the classification system of Köppen, modified by García de Miranda (1973), the climates of Aguascalientes correspond to the semi-arid *BS* and the temperate *C(w)* climate groups, accounting for approximately 86% and 14% of the state, respectively (Table 2). Each group is further subdivided according to rainfall amount and season, temperature regime, and elevation, etc. (Table 2). Temperate climates occur in the mountainous areas of the Sierra Fría and Sierra del Laurel. The highest average annual rainfall (600–800 mm) occurs in the highest elevations (>2500 m) of the Sierra Fría and Sierra del Laurel where annual temperatures average 12–18°C. Summer rainfall defines the two temperate climate subtypes *C(w₀)* and *C(w₁)* and predominates in the semi-arid subtypes (*BS₁kw(w)* and *BS₁hw(w)*), but some winter rainfall occurs in the most widespread subtype, *BS₁kw*, in the semi-arid climate category that affects 63.8% of the state (Table 2). The warmest temperatures occur in semi-arid subtype *BS₁hw(w)* where annual values average 18–21°C.

Floristically, the state of Aguascalientes belongs to two regions: the Mexican Xerophytic and, to a lesser extent, the Mountain Mesoamerican (Rzedowski 1978). The major types of vegetation found in Aguascalientes are: (1) temperate vegetation, located in the mountain ranges, in the municipalities of San José de Gracia and Calvillo, with temperate forests (*Quercus*, *Pinus*, *Juniperus* and *Cupressus* forests with their respective mixtures), manzanita scrub and temperate grasslands; (2) tropical vegetation distributed in the southwest in the municipalities of Calvillo and Jesús María, with subtropical scrub and tropical deciduous forest as the main communities; (3) xerophytic vegetation localized in the north-central part of the state, including an extensive crassicaul thorn scrub and xeric grassland, in the municipalities of Aguascalientes, Cosío, El Llano and Jesús María, and microphyll scrub in Asientos and Tepezalá; and (4) small patches of riparian vegetation along natural and artificial bodies of water distributed state-wide (CONABIO-IMAE-UAA 2008).

MATERIALS AND METHODS

Field Work and Data Analysis

Field work was conducted weekly throughout the state over four years, resulting in a total of 320 records of gymnosperms across their distribution range. Gymnosperm collections from Aguascalientes were reviewed in the MEXU and HUAA herbaria. The specimens were processed according to Lot and Chiang (1986) and identification of the material was carried out with specialized bibliography (Martínez 1948, 1963;

Rzedowski and McVaugh 1966, 1972; Zanoni and Adams 1979; McVaugh 1992; Stevenson 1993; Thieret 1993; Zamudio and Carranza 1994; Villanueva-Almanza and Fonseca 2011; and Adams 2014). Nomenclature of gymnosperm species follows Gernandt and Pérez de la Rosa (2014), except for *Cupressus lusitanica*, which in their paper is accepted as *Callitropsis lusitanica* (Mill.) D.P. Little (Little 2006). The NOM-059 and the IUCN Red List were reviewed to find any threatened gymnosperm species in Aguascalientes. Vegetation types were assigned according to Siqueiros et al. (2016). Oak-pine and pine-oak forests differ in the relative dominance of pine and oak.

RESULTS

Fifteen species of gymnosperm belonging to five genera and three families were recorded for Aguascalientes. The most abundant and diverse genus is *Pinus* with eight species, followed by *Juniperus* with four, and *Cupressus*, *Taxodium* and *Ephedra* with only one species each (Table 1). Among the pines, *P. teocote* and *P. leiophylla* are the most abundant species, while *P. strobiformis* is the scarcest. The most abundant *Juniperus* species is *J. deppeana*, while *J. coahuilensis* is the least frequent and only some old trees survive. Three of the fifteen species (*Cupressus lusitanica*, *Pinus strobiformis* and *P. durangensis* [as *P. martinii*]) are in the NOM-059 in the Pr category (subject to special protection) and in the IUCN Red List of Threatened Species (2015) in the LC (least concern) category. Twelve species (all *Pinus* species plus *Cupressus lusitanica*) are distributed in the mountainous region in the municipalities of Calvillo, Jesús María and San José de Gracia; *Taxodium mucronatum* occurs in the municipalities of Aguascalientes and Jesús María, and *Ephedra* in Asientos and Tepezalá (Table 1).

Cypress Communities (*Cupressus lusitanica*)

Cupressus lusitanica, commonly called Mexican cypress, is distributed from Mexico southward throughout Central America to Bolivia. The origin of this species is controversial. According to Eckenwalder (2009) Mexican populations were introduced from Portugal. However, Martínez (1963) and Farjon (1993) stress its American origin, a fact that was overlooked after its early introduction to Portugal in 1645. In Aguascalientes, the earliest mention is by González (1881), who noted the presence of cypress and ahuehetes (*Taxodium mucronatum*) in the State. The cypress forests in Aguascalientes comprise deteriorated communities, usually of primary origin, established in the bottom of sheltered wet canyons with accumulation of alluvium and sedimentary rocks, at elevations of 2200–2500 m. The cypresses usually run along ravines, associated with other species with high moisture requirements such as *Arbutus* spp. or *Garrya* spp. However, on the slopes of the canyons we can often find other types of plant associations, depending on steepness and exposure, such as oak or pine forests, or other riparian elements such as *Populus tremuloides* Michx. or *Arbutus tessellata* P.D. Sørensen. These forests are located in the municipalities of Calvillo, Jesús María and San José de Gracia and are characterized by the dominance of white cedar or cypress that can grow to 30 m high. Although scarce, difficult access to most of the cypress forests has led to their preservation. Some localities where preserved cypress forests can be found are: Barranca los Planes (Sierra de Guajolotes, San José de Gracia), Barranca Pilares

Table 1. Gymnosperm species recorded in the municipalities and plant communities of Aguascalientes, Mexico.

Family	Genus	Species	Municipalities	Plant Community
Cupressaceae	<i>Cupressus</i>	<i>C. lusitanica</i> Mill.	Calvillo, San José de Gracia	Oak-cypress forest
	<i>Juniperus</i>	<i>J. coahuilensis</i> (Martínez) Gaussen ex R.P. Adams	Rincón de Romos	Natural grassland
		<i>J. deppeana</i> Steud.	San José de Gracia	Oak-juniper forest
		<i>J. durangensis</i> Martínez	Calvillo, San José de Gracia	Oak-juniper forest
		<i>J. martinzii</i> Pérez de la Rosa	Calvillo, Jesús María, San José de Gracia	Oak-juniper forest
Ephedraceae	<i>Taxodium</i>	<i>T. mucronatum</i> Ten.	Aguascalientes, Calvillo, Jesús María	Gallery forest
	<i>Ephedra</i>	<i>E. compacta</i> Rose	Asientos y Tepezalá	Microphyll xerophytic scrub
Pinaceae	<i>Pinus</i>	<i>P. cembroides</i> Zucc.	San José de Gracia	Pine-oak forest
		<i>P. chihuahuana</i> Engelm.	Calvillo, San José de Gracia	Oak-pine forest, pine-oak forest
		<i>P. devoniana</i> Lindl.	San José de Gracia	Pine-oak forest
		<i>P. durangensis</i> Martínez	Calvillo, San José de Gracia	Oak-pine forest, pine-oak forest
		<i>P. leiophylla</i> Schiede ex Schtdl. & Cham.	San José de Gracia	Oak-pine forest, pine-oak forest
		<i>P. lumholtzii</i> B.L. Rob. & Fernald	Calvillo, San José de Gracia	Oak-pine forest, pine-oak forest
		<i>P. strobiformis</i> Engelm.	San José de Gracia	Pine-oak forest
		<i>P. teocote</i> Schtdl. & Cham.	San José de Gracia	Oak-pine forest, pine-oak

(Sierra de San Blas de Pabellón, Calvillo), Barranca las Palomas (Jesús María), Barranca Adjuntas (Monte Grande de Sierra Fría, San José de Gracia), Barranca Cedros (Sierra de Guajolotes) and Ojo de Agua del Arriero (Boca Oscura stream, Sierra del Laurel). The community of Barranca los Planes is the largest, relatively well preserved and diverse, with abundant juveniles and evidence of recruitment. In contrast, the population of Barranca Ojo de Agua del Arriero is the smallest and the most affected by human activity (Siqueiros 1999; Rodríguez-Ávalos 2014). The situation of the cypress forest can be considered in decline due to logging for local use and degradation of habitat. It covers an area of 1.49 km², representing only 0.16% of the total area of the Aguascalientes temperate forest, although previously this forest likely was more widely distributed. Given that cypress forest is confined to the fringes of permanent streams with a constant supply of water, its recovery is extremely improbable because of the replacement of these permanent streams by seasonally wet streams that receive water only during the rainy season. The cur-

rent distribution of cypress forest is patchy, each patch covering a relatively small area, and most are at the primary successional stage, albeit with different degrees of disturbance. This species is mentioned in the NOM-059 (SEMARNAT 2010) list in the category Pr (special protection).

Juniper Communities (Juniperus spp.)

Four species of juniper are located in Aguascalientes: *Juniperus coahuilensis*, *J. deppeana*, *J. durangensis*, and *J. martinzii*. The juniper forests cover an area of 12.67 km². LeSueur (1945), Gentry (1957) and Rzedowski (1978), among others, have proposed a secondary origin of juniper forests. In Aguascalientes, the juniper forests are communities of rapid recovery, and it is common to find a great number of juvenile trees in openly grazed areas as secondary vegetation on land cleared for livestock that was previously occupied by pine-oak forests at elevations of 2300–2700 m. Usually, these forests are open,

Table 2. Climate types in Aguascalientes (INEGI 2008) classified according to the Köppen system (modified by García et al. 1973).

Group	Subtype	Description	Rainfall season	Average annual temperature [°C]	Average annual rainfall [mm]	Elevation [m]	Distribution in state [%]
Semi-arid	<i>BS₁kw</i>	Temperate semi-dry	Winter rains 5–10.2% of annual precipitation	14–18	400–700	1800–2000	63.8
	<i>BS₁kw(w)</i>	Temperate semi-dry with summer rains	Winter rains <5% of annual precipitation	16–18	400–600	1800–1950	n/a
	<i>BS₁hw(w)</i>	Semi-dry semi-warm with rains	Mainly summer	18–21	500–700	1700–1900	13.6
Temperate	<i>C(w₀)</i>	Sub-humid temperate with summer rains and lower humidity	Summer only	12–18	600–700	2200–2500	10.2
	<i>C(w₁)</i>	Sub-humid temperate	Summer only	12–18	600–800	>2500	3.4

composed of short trees, sometimes shrubby, 3–8 (15) m high, with well defined stratification, and a dense herbaceous stratum. They are established on flat to slightly undulating land such as plateaus or beds of canyons in the mountainous part of the state, in alluvial soils derived from igneous rocks or tuff with deep soils of moderate drainage. Although these forests are of secondary origin and are considered to represent successional stages after the clearing of oak or pine (Rzedowski 1978), their condition varies depending on the geographical location of the forest. Some maintain an abundant and vigorous plant cover, with tall and healthy trees. However, there are also deteriorated communities, with clear signs of soil erosion, especially in areas used for grazing. According to Chapa-Bezanilla et al. (2008), the juniper forest had a barely noticeable increase in surface area from 1956 to date, despite the fact that one would expect a clear improvement when forest pressure decreased in the early twentieth century. The authors interpret this as the woodland utilization rate being equal to the recovery, such that an increase in coverage is not observed. However, Minnich et al. (1994), based on aerial photography, mention a recovery of juniper populations in recent decades in the same area. Because these forests are open, they develop an abundant ground cover, so they are usually exploited for grazing. Grazing is one of the main causes of the continued deterioration of this type of forest, besides water and wind erosion. Another historical disturbance is the clearing of land for farming, which—if neglected—causes problems of erosion and weed invasion. There are no reliable records of the exploitation of juniper forests in the area; however, they may have been cleared to allow agricultural activities.

Juniperus coahuilensis is native to the semi-arid southern plains bordering the Chihuahuan Desert to the east and west, extending from Chihuahua to Aguascalientes and Guanajuato. It occupies hills and piedmont slopes formed by outcrops of limestone and paleo-lake sediments that compose the Green River-San Pedro River basin. Currently this species is rare in the state, occurring as two disjoint populations in the north and south of Aguascalientes. However, it likely was part of an old corridor of calcicolous scrub with a continuous distribution from southern Zacatecas to Los Altos de Jalisco via the rolling hills crossing the Valley of Aguascalientes. It can be found between elevations of 2100 and 2400 m in climates ranging from temperate semi-dry to temperate sub-humid, associated with oak forests and natural grasslands. In lowlands it forms low and open scrub, but in the valleys and slopes it can rise to communities up to 8 m high and with a closed canopy. The best-preserved *J. coahuilensis* community is located in the valleys and piedmont of the Chiquihuitillo hill, north of Rincón de Romos, in the direction of Zacatecas City, where this plant community continues. Another population occurs at the southern end of the state near Tanque de los Jiménez. However, the original population was removed for posts, firewood and wood for making various utensils and regional crafts, so only a few junipers remain as a mature community.

Juniperus deppeana is widespread from the southwestern US as far as Puebla, Mexico, and in Aguascalientes it is the most abundant gymnosperm species, occurring in deep alluvial soils in San José de Gracia municipality (Díaz et al. 2012). It can be the dominant element of the forest and forms one of the most attractive forest communities for recreation, given the relatively flat land that it occupies, its easy access, and its scenic beauty.

This species can form pure forest or be associated with pine or oak forests, at elevations of 2400–2550 m (Siqueiros 1999).

Juniperus durangensis is distributed throughout north-central Mexico (Aguascalientes, Chihuahua, Durango, Jalisco, Sonora, Zacatecas), growing in oak, pine or mixed forests. Although apparently rare throughout its range and previously considered vulnerable (Farjon 2005), its status in the IUCN is LC (least concern [IUCN 2015]). In Aguascalientes it is also rare, located in the municipalities of Calvillo and San José de Gracia, as elements of oak and pine forest or scrubland, at elevations of 2340–2850 m, mainly on humid slopes or near streams. It is never the dominant element.

Juniperus martinezii is restricted to small, local populations in rocky areas (Adams et al. 1990). It grows in pine-oak forest and woodland and in oak woodland, often on calcareous soils, at elevations of 1950–2500 m. In Aguascalientes it is distributed in the municipalities of Calvillo, Jesús María, and San José de Gracia, in plateaus and slopes of shallow canyons of the Sierra Fría and Sierra del Laurel. It is never found as the dominant element. Given its restricted distribution range, this species fulfills the criteria for listing as Vulnerable.

Ahuehete Communities (Taxodium mucronatum)

The “ahuehetes” in Aguascalientes are located on the banks of ancient streams like rivers or springs. They form gallery forests in the municipalities of Aguascalientes, Calvillo and Jesús María. Formerly, streams and rivers in the state usually had gallery forests dominated by *Taxodium mucronatum* (González 1881), often accompanied by *Populus fremontii* S. Watson, *Salix bonplandiana* Kunth, *S. humboldtiana* Willd. and *Fraxinus uhdei* (Wenz.) Lingelsh. Today, it is rare to find preserved ahuehete forests, which mostly have been cut, resulting in secondary forests of *Salix* spp. or *Schinus molle* L. Sometimes, they have been completely eradicated along dry riverbeds of urban areas, leaving only shrubs like *Baccharis heterophylla* Kunth, *B. salicifolia* (Ruiz & Pav.) Pers. or *Salix taxifolia* Kunth. However, we can still find a few places where the ahuehete forest is preserved, with old and large trees such as the Sabinal in the city of Aguascalientes. In these conserved sites it is common for old trees to form a dense canopy over the surface of the water, with trees up to 25 m high.

Pine Communities (Pinus spp.)

Eight species of pines have been recorded for Aguascalientes: *Pinus cembroides*, *P. chihuahuana*, *P. devoniana*, *P. durangensis*, *P. leiophylla*, *P. lumholtzii*, *P. strobiformis* and *P. teocote* (Siqueiros 1999). *Pinus strobiformis* was discovered as late as 2014 by the Consejo Nacional Forestal (CONAFOR) in a very inaccessible location in Monte Grande de Sierra Fría, Aguascalientes being the most southern distribution of the species. Out of the eight *Pinus* species, four are scarce with very small populations (*Pinus cembroides*, *P. devoniana*, *P. durangensis* and *P. strobiformis*). In Aguascalientes, pines are usually associated with oaks or junipers. Pure communities are extremely scarce, covering only about 27 km² (0.5% of the total vegetation cover of the state). Of those, a little over 62% are conserved forests, while the rest represent secondary forests. The limited area of pure pine stands has long been located on private land. Thanks to this, some of these forests have remained as primary communities with different degrees of disturbance.

Logging, fires, severe droughts and pests through the years have gradually decimated populations of pine, eradicating them from many sites and preventing estimates of their possible original range. The intense exploitation of forest products occurred during three decades (1920s to 1950s) of logging, and charcoal production caused a negative impact on the density of pine and oak forests. However, information about historical use of these forests is limited. On the other hand, forest fires also contributed to the reduction of temperate forests in Aguascalientes. A severe fire in 1993 that devastated Monte Grande de Sierra Fría was recorded as having consumed an area of 6000 ha. There are records of at least nine fires per year over the past 14 years (Asociación Sierra Fría 2005). Comparing aerial photos from 1970 to 1993, Minnich et al. (1994) discovered high mortality of *P. leiophylla* due to the 1984 drought, weakening the forest and making it prone to pests such as *Dendroctonus mexicanus* Hopkins. Pests have been another decisive factor in the pine populations' decline in the state. Several infestations were detected over the past 30 years. During 2001, about 10,000 pines were destroyed by *Dendroctonus mexicanus* in the Sierra Fría (Sánchez-Martínez 2004). According to Chapa-Bezanilla et al. (2008), pine forest in Aguascalientes increased significantly in surface area from 1956 to date, indicating that there was recruitment of new individuals, and showing a moderate recovery despite the pressures of natural (infestations of bark beetles) or anthropogenic origin (logging or "sanitation"). Most pine populations have been preserved on the southern flank of the region known as Monte Grande at the top of the Sierra Fría, as well as in some canyons that descend toward the southeast. Currently, there are scattered pine forests growing in the western escarpment of the Sierra Fría, in the eastern highlands near the town of La Congoja and in the high plateaus in the southern part of the mountains. Pine forests in the state establish at elevations ranging from 1790 to 2800 m, depending on the species.

Pinus cembroides in Aguascalientes forms scarce populations in the San José de Gracia municipality. It is believed that populations originally occupied the middle and lower slopes at the foot of the mountains and temperate grasslands between 2350 and 2400 m, usually in thin and poor mountain soils on steep slopes (lithosols). Today, unfortunately, only few populations survive, usually associated with oaks, rarely as pure stands (Rodríguez-Ávalos 2014). Only two populations have been recorded in Aguascalientes, one in Mesa de Hierba Anís and one in the Sierra de Guajolotes, the latter with non-viable seeds.

Pinus chihuahuana populations are rare in Aguascalientes. Commonly they occur as scattered individuals, often associated with *Pinus leiophylla*, *P. teocote* or *Quercus* spp., in mixed forests and woodlands. They thrive on flat terrain, gentle slopes, or in the bottom of canyons in deep and loamy soils (Vertisols) between 2250 and 2700 m in San José de Gracia and Jesús María municipalities.

Pinus devoniana is distributed from central Mexico to Guatemala. Aguascalientes and Zacatecas represent its most northern distribution in the Sierra Madre Occidental. This species was reported before as *P. michoacana* Martínez var. *cornuta* Martínez (Siqueiros 1999). In the state, *P. devoniana* is represented by only a few isolated individuals mixed with other pine species and oaks, usually on humid slopes, in the municipality of San José de Gracia from 2450 to 2650 m. It is a very scarce species.

Pinus durangensis is also very scarce in the state. It is distributed in the municipalities of Calvillo, Jesús María and San José de Gracia, forming populations of few trees in oak-pine forests, usually on high peaks, wet slopes or in the beds of ravines between 2450 and 2800 m. The species is included in the NOM-059 list as subject to special protection under its synonym *Pinus martinezii* E. Larsen (Gernandt and Pérez de la Rosa 2014). It is difficult to establish whether their populations were more extensive in the past and whether their decline was caused by natural or anthropogenic factors.

Pinus leiophylla is one of the most common species in the Aguascalientes pine forests; it can form pure patches, but it is usually associated with *P. teocote*, oaks and other forest elements such as *Prunus serotina* Ehrh. or *Arbutus* spp. *Pinus leiophylla* is located along streams and on wet slopes with northern exposure in the Sierra Fría, forming relatively pure stands in some localities such as "El Guaro", the Sierra de San Blas de Pabellón (Sánchez-Martínez 2004), or some areas of the Sierra del Pinal. Also, it can grow in high plateaus such as Mesa el Águila or Mesa el Aserradero (Minnich et al. 1994) between 2200 and 2700 m.

Pinus lumholtzii is called "sad pine" for its pendulous foliage. It rarely forms pure stands and usually occurs in very small populations in association with *Quercus jonesii* Trel. and sometimes *P. durangensis*. It inhabits low hills with poor soil, low plateaus or gentle slopes on land composed of outcrops of acid tuff between 2300 and 2800 m in San José de Gracia and Calvillo.

Pinus teocote is the most common species distributed in Aguascalientes, usually on very gentle or relatively flat topography such as in drier plateaus and middle slopes. It forms mixed forest, associated either with other species of pine or oaks, or forms pure patches (Siqueiros 1999), mainly in the municipalities of Jesús María and San José de Gracia at 1640 to 2830 m. The wood of this pine is strong and of good quality, contributing to its extensive use for construction and as fuel.

Pinus strobiformis is the scarcest species in the Aguascalientes temperate forests. This record constitutes the southernmost stand of its distribution. Only one population is known in Monte Grande de Sierra Fría. It is located on slopes with outcrops of acidic tuff on the highest peaks of the Sierra Fría on the border to Zacatecas at 2799 m in the municipality of San José de Gracia. Trees are scattered in the forest, mixed with *P. teocote*, *P. lumholtzii*, *Quercus jonesii*, *Q. sideroxylla* Bonpl., *Juniperus deppeana* and *Arctostaphylos pungens*.

Ephedra Communities

In Aguascalientes there is only one species of *Ephedra*, *E. compacta*, commonly associated with other shrubs of microphyll scrub such as *Calliandra eriophylla*, *Jatropha dioica* Sessé, *Condalia warnockii*, or *Purshia plicata* (D. Don) Henrickson, among others. It is occasionally associated with desert grasslands composed of *Aristida purpurea* Nutt., also common in this area of Aguascalientes. It is located on calcareous slopes, hills and piedmont to the south of the Sierra de Tepezalá and Asientos. The *Ephedra* community has been recorded only for Tepezalá and Asientos, two municipalities in the northeast of Aguascalientes, and possibly represents a continuation of the microphyll scrub of the Chihuahuan desert. It occupies approximately 71.7 km², which represents 10.7% of the xerophyllous

scrub of the State. The microphyll desert scrubland occurs on gentle limestone hills extending from the Sierra de Tepezalá to the south, until it reaches the edge of the Chicalote river basin. It establishes preferentially on outcrops of Cretaceous marine sedimentary rocks and their alluvial debris on shallow and poor soils with a high content of calcium carbonates. The current situation of the microphyll desert scrubland is worrying. It has been heavily damaged by anthropogenic activities ranging from underground and strip mining to overgrazing by horses, cattle, and goats. As a consequence, it is estimated that 80% of these communities are in a secondary condition. At present, mining activities in this region are threatening the existence of this unique plant community in Aguascalientes. It is essential to set aside areas of exclusion or reserves for implementation of long-term conservation plans.

DISCUSSION AND CONCLUSION

We recorded 15 gymnosperm species from Aguascalientes. Given that Gernandt and Pérez de la Rosa (2014) have been working on Mexican conifers for a long time, we follow their treatment rather than those of Eckenwalder (2009) or Farjon and Styles (1997). For instance, we use *Juniperus martinezii* instead of *J. flaccida* Schltdl. var. *martinezii* (Pérez de la Rosa) Silba and *Pinus chihuahuana* instead of *P. leiophylla* var. *chihuahuana* (Engelm.) Shaw. We tried to explore even the most hidden and inaccessible sites; however, there is always the possibility of finding something new. According to Villaseñor (2016), there are 23 gymnosperm species in Aguascalientes. However, during 30 years of botanical exploration we found only the 15 species documented here. Villaseñor mentioned, for instance, *Abies religiosa* (Kunth) Schltdl. & Cham., *Pinus hartwegii* Lindl., *P. oocarpa* Schiede ex Schltdl., or *Podocarpus matudae* Lundell, among others. However, requirements of these species are far from the climatic or topographic characteristics of the State. Besides, he does not mention any precise locality or bibliographic source for these species records.

Although Aguascalientes is one of the smallest Mexican states, its richness in conifers is good. This may be partly a function of a high species-to-area ratio due to thorough field work combined with the small size of the state. For instance, Aguascalientes possesses 14 conifer species in 5618 km² (2,492 × 10⁻³ species/km²), compared with larger states such as Jalisco with 36 species (Rodríguez-Contreras 2010) in 78,588 km² (4.6 × 10⁻⁵ species/km²) or Oaxaca with 24 species (Del Castillo et al. 2004) in 93,757 km² (2.6 × 10⁻⁵ species/km²).

The most abundant conifer species in the Aguascalientes forests are *Juniperus deppeana*, *Pinus teocote* and *P. leiophylla*, followed by *P. lumholtzii*, *P. durangensis* and *P. cembroides*. The remaining species are very scarce, with scattered individuals among other forest elements or along ancient water courses. The scarcest species are *Pinus strobiformis* and *Juniperus coahuilensis*, the juniper represented only by one or two individuals. Most of the decline in the pine populations is probably due to intense logging in past times and prolonged severe droughts and pests. On the other hand, the beauty of the area and the need to provide the human population with nearby recreational areas make it necessary to facilitate access to the mountains. The creation of new human settlements or the growth of existing rural areas, commercial and agricultural use of land and overgrazing are factors of a social type that have favored the depletion of the

forest area as a whole. Regarding *Ephedra compacta*, despite the fact that its populations are in good shape so far, its natural habitat is threatened by mining activities that are growing in this part of the state.

Finally, in order to maintain our natural plant communities in good condition, it is imperative to establish programs to conserve a healthy and stable natural heritage that our children will inherit.

LITERATURE CITED

- ADAMS, R. P. 2014. Junipers of the world: the genus *Juniperus*, 4th edition. Trafford Publishing Co., Bloomington, IN. 422 p.
- , J. A. PÉREZ DE LA ROSA AND M. CHARZARO. 1990. The leaf oil of *Juniperus martinezii* Pérez de la Rosa and taxonomic status. *Journal of Essential Oil Research* 2: 99–104.
- ASOCIACIÓN SIERRA FRÍA. 2005. Diagnóstico de recursos naturales del área natural protegida Sierra Fría, Aguascalientes. Asociación Sierra Fría, Aguascalientes, Mexico. 101 p.
- BOLIO, A. E., DE LA PUENTE, J. M., R. MONCALLO AND S. VILLA. 1970. Estudio de la vegetación forestal del Estado de Aguascalientes. Inventario Nacional Forestal. Mexico.
- BOWE, L. M., G. COAT, and C.W. DE PAMPHILIS. 2000. Phylogeny of seed plants based on all three genomic compartments: extant gymnosperms are monophyletic and Gnetales' closest relatives are conifers. *Proc. Natl. Acad. Sci. U.S.A.* 97: 4092–4097.
- CARVAJAL, S. AND R. MCVAUGH. 1992. *Pinus*. In R. McVaugh and W. R. Anderson [eds.], Gymnosperms and pteridophytes. Flora Novo-Galiciana 17. University of Michigan Herbarium, Ann Arbor. 467 p.
- CHAPA-BEZANILLA, D., J. SOSA RAMÍREZ AND A. ALBA-ÁVILA. 2008. Estudio multitemporal de fragmentación de los bosques en la Sierra Fría, Aguascalientes, México. *Madera y Bosques* 14: 37–51.
- CHASE, M.W. AND J. L. REVEAL. 2009. A phylogenetic classification of the land plants to accompany APG III. *Bot. J. Linn. Soc.* 161: 122–127.
- CHAW, S. M., C. L. PARKINSON, Y. CHENG, T. M. VINCENT AND J. D. PALMER. 2000. Seed plant phylogeny inferred from all three plant genomes: monophyly of extant gymnosperms and the origin of Gnetales from conifers. *Proc. Natl. Acad. Sci. U.S.A.* 97: 4086–4091.
- CONABIO. 1998. La diversidad biológica de México: estudio de país, 1998. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Mexico.
- CONABIO-IMAE-UAA. 2008. *La biodiversidad en Aguascalientes: estudio de estado*. Mexico. 389 p.
- CONTRERAS-MEDINA, R., I. LUNA-VEGA AND J. J. MORRONE. 2007. Gymnosperms and cladistic biogeography of the Mexican Transition Zone. *Cladistic Biogeography* 56: 905–915.
- DEL CASTILLO, R. F., J. A. PÉREZ DE LA ROSA, G. VARGAS-AMADO AND R. RIVERA-GARCÍA. 2004. Coníferas, pp. 141–158. In A. J. García Mendoza, M. J. Ordóñez and M. Briones Salas [eds.], Biodiversidad de Oaxaca. UNAM, Fondo Oaxaqueño para la Conservación de la Naturaleza and World Wildlife Fund, México and Oaxaca, Mexico.
- DÍAZ, V., J. SOSA R. and D. PÉREZ-SALICRUP. 2012. Distribución y abundancia de las especies arbóreas y arbustivas en la Sierra Fría, Aguascalientes, México. *Polibotánica* 34: 99–126.
- ECKENWALDER, J. E. 2009. Conifers of the world. Timber Press, Portland, OR.
- ESPINOSA-GARDUÑO, J. 2001. Gymnospermae, pp. 44–55. In G. C. de Rzedowski, J. Rzedowski [eds.], Flora fanerogámica del Valle de México, 2nd edition. Instituto de Ecología A. C.-Conabio, Pátzcuaro, Michoacán, Mexico.
- FARJON, A. 1993. Nomenclature of the Mexican cypress or “cedar of Goa”, *Cupressus lusitanica* Mill. (Cupressaceae). *Taxon* 42: 81–84.
- . 2005. Monograph of *Cupressaceae* and *Sciadopitys*. Royal Botanic Gardens, Kew, Richmond, Surrey, UK.

- AND T. B. STYLES. 1997. *Pinus* (Pinaceae). *Fl. Neotrop. Monogr.* **75**: 1–291. New York Botanical Garden, New York.
- GARCÍA, R. G., O. ROSALES, M. DE LA CERDA AND M. E. SIQUEIROS. 1999. Listado florístico del Estado de Aguascalientes. *Scientiae Naturae*, vol. 1(2): 5–51.
- GARCÍA-ARÉVALO, A. AND M. S. GONZÁLEZ-ELIZONDO. 2003. Pináceas de Durango, 2nd edition. Instituto de Ecología A. C., Xalapa, Mexico. 187p.
- GARCÍA DE MIRANDA, E. 1973. Modificaciones al sistema de clasificación climática de Köppen, UNAM, México, D.F., Mexico.
- GENTRY, H. S. 1957. Los pastizales de Durango. Ediciones del Instituto Mexicano de Recursos Naturales Renovables, México, D.F., Mexico. 361 p.
- GERNANDT, D. S. AND J. A. PÉREZ DE LA ROSA. 2014. Biodiversidad de Pinophyta (coníferas) en México. *Revista Mexicana de Biodiversidad, Suppl.* **85**: S126–S133.
- GONZÁLEZ, A. R. 1881. Historia del Estado de Aguascalientes. Librería, Tipografía y Litografía de V. Villada, México, Mexico. 562 p.
- GRANADOS-SÁNCHEZ, D., A. SÁNCHEZ-GONZÁLEZ, R. L. GRANADOS-VICTORINO AND A. BORJA DE LA ROSA. 2011. Ecología de la vegetación del Desierto Chihuahuense. *Revista Chapingo. Serie ciencias forestales y del ambiente* **17**: 111–130.
- INEGI. 1981. Síntesis geográfica del estado de Aguascalientes. Secretaría de Programación y Presupuesto. México D.F., Mexico. 98 p.
- . 2008. Descripción del medio físico. Relieve, pp. 24–26. *In* CONABIO, IMAE, INEGI, UAA [eds], Estrategia de Estado de la Biodiversidad de Aguascalientes, Mexico.
- IUCN. 2015. The IUCN Red List of Threatened Species, vers. 2015-4. <http://www.iucnredlist.org> (19 Nov 2015).
- LESUEUR, H. 1945. The ecology of the vegetation of Chihuahua, Mexico, north of parallel 28. University of Texas Publisher 4521, Austin. 92 p.
- LITTLE, D. P. 2006. Evolution and circumscription of the true cypresses (Cupressaceae: *Cupressus*). *Syst. Bot.* **31**: 461–480.
- LOT, A. AND F. CHIANG. 1986. Manual de herbario (Administración y manejo de colecciones, técnicas de recolección y preparación de ejemplares botánicos). Consejo Nacional de la Flora de México, Mexico. 142 p.
- LU, Y., J. H. RAN, D. M. GUO, Z. Y. YANG AND X. Q. WANG. 2014. Phylogeny and divergence times of gymnosperms inferred from single-copy nuclear genes. *PLoS ONE* **9**(9), e107679.
- MARTÍNEZ, M. 1948. Los pinos mexicanos, 2nd edition. Ediciones Botas, Mexico. 367 p.
- . 1963. Las pináceas mexicanas, 3rd edition. Universidad Nacional Autónoma de México, Mexico. 400 p.
- MCVAUGH, R. 1992. Flora Novo-Galiciana: A descriptive account of the vascular plants of western Mexico, vol. 17: gymnosperms and pteridophytes. 462 p. University of Michigan Herbarium, Ann Arbor, MI.
- MINNICH, R., J. SOSA R., V. E. FRANCO, J. BARRY AND M. E. SIQUEIROS. 1994. Reconocimiento preliminar de la vegetación y de los impactos de las actividades humanas en la Sierra Fría, Aguascalientes, México. *Investigación y Ciencia* **12**: 23–29.
- PÉREZ DE LA ROSA, J. A. 1985. Una nueva especie de *Juniperus* de México. *Phytologia* **58**: 365–370.
- RODRÍGUEZ-ÁVALOS, J. A. 2014. Análisis espacial de la vegetación de Aguascalientes. Distribución geográfica y descripción de las comunidades vegetales naturales de Aguascalientes. Ph.D. dissertation, Universidad Autónoma de Aguascalientes, Mexico. 295 p.
- RODRÍGUEZ-CONTRERAS, A. 2010. Riqueza florística de Jalisco. Foro la Biodiversidad en Jalisco. Universidad de Guadalajara, Guadalajara, Mexico.
- RZEDOWSKI, J. 1978. Vegetación de México. Ed. Limusa, México, D.F., Mexico. 423 p.
- AND R. MCVAUGH. 1966. La vegetación de Nueva Galicia. *Contr. Univ. Michigan Herb.* **9**(1): 1–123.
- AND R. MCVAUGH. 1972. Nota sobre la flora del NE del Estado de Aguascalientes (México). *Annales de la Escuela Nacional de Ciencias Biológicas* **19**: 31–43.
- SÁNCHEZ-DURÓN, A., J. M. LEÓN, P. SOTO, R. MEZA AND J. MARTÍNEZ. 1967. Pastizales nativos y su capacidad forrajera en el estado de Aguascalientes. Nacional Financiera, S.A. Plan Asistencia Técnica, Guadalajara, Mexico. 29 p.
- SÁNCHEZ-MARTÍNEZ, G. 2004. Diagnóstico fitosanitario de los bosques de pino, pino-encino y encino-pino en la Sierra Fría, Aguascalientes. Informe Final. INIFAP, Mexico. 30 p.
- SEMARNAT. 2010. 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. Diario Oficial de la Federación, 30 de Diciembre de 2010 [30 Dec 2010].
- SIQUEIROS, M. E. 1999. Coníferas de Aguascalientes. Universidad Autónoma de Aguascalientes, Aguascalientes, Mexico. 67 p.
- , J. A. RODRÍGUEZ-AVALOS, J. MARTÍNEZ-RAMÍREZ AND J. C. SIERRA-MUÑOZ. 2016. Situación actual de la vegetación del estado de Aguascalientes, México. *Botanical Sciences* **94**(3): 455–470 ([doi: 10.17129/botsci.466](https://doi.org/10.17129/botsci.466)).
- STEVENSON, D. W. 1993. Ephedraceae, pp. 428–434. *In* Flora of North America Editorial Committee [ed.], Flora of North America, vol. 2. Oxford University Press, New York.
- THERET, J. W. 1993. Pinaceae, pp. 352–398. *In* Flora of North America Editorial Committee [ed.], Flora of North America, vol. 2. Oxford University Press, New York.
- VILLANUEVA-ALMANZA, L. AND R. M. FONSECA. 2011. Revisión taxonómica y distribución geográfica de *Ephedra* (Ephedraceae) en México. *Acta Bot. Mex.* **96**: 79–116.
- VILLASEÑOR, J. L. 2016. Checklist of the native vascular plants of Mexico. *Revista Mexicana de Biodiversidad* **87**(3): 1–344.
- ZAMUDIO, S. AND E. CARRANZA. 1994. Cupressaceae. *Flora del Bajío y Regiones Adyacentes* **29**: 1–21.
- ZANONI, T. A. AND R. P. ADAMS. 1979. The genus *Juniperus* (Cupressaceae) in Mexico and Guatemala: synonymy, key, and distributions of the taxa. *Bol. Soc. Bot. México* **39**: 83–121.