

## THE TROPICAL MADREAN FLORA OF YÉCORA, SONORA, MEXICO

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### ABSTRACT

The Municipio de Yécora is in the Tropical Madrean zone of the Sierra Madre Occidental in eastern Sonora, Mexico. The flora is very diverse with 1777 taxa in 150 families and 687 genera. The most important families and genera are Asteraceae (14.5% of the flora), Poaceae (11.3%), and Fabaceae (10.6%), *Muhlenbergia* (38 taxa), *Euphorbia* (31 taxa), *Cyperus* (29 taxa), *Ipomoea* (26 taxa), *Quercus* (23 taxa including 7 hybrids), and *Dalea* (22 taxa). Herbaceous plants dominate the flora (71.3%). Twenty-one species in the Yécora flora have protection in NOM-059-SEMARNAT-2010. Non-native species are 6.2% of the flora but only buffelgrass (*Pennisetum ciliare*) in the tropical lowlands and Natal grass (*Melinis repens*) in grassland and oak woodland are invasive in natural habitats.

Vegetation is zoned from foothills thornscrub and tropical deciduous forest in the lowlands to oak woodland and pine-oak forest in the uplands. Plant species diversity increases with elevation and rainfall, peaking in pine-oak forest. The Yécora flora in the Madrean Tropical Madrean zone serves as a baseline to evaluate Madrean affinities in floras in the Madrean Archipelago in northeastern Sonora and southeastern Arizona.

### RESUMEN

El Municipio de Yécora se localiza en la zona Madre Tropical de la Sierra Madre Occidental al este de Sonora, México. La flora es muy diversa, con 1777 taxones en 150 familias y 687 géneros. Las familias y géneros más importantes son Asteraceae (14.5% de la flora), Poaceae (11.3%) y Fabaceae (10.6%), *Muhlenbergia* (38 taxones), *Euphorbia* (31 taxones), *Cyperus* (29 taxones), *Ipomoea* (26 taxones), *Quercus* (23 taxones, incluye 7 híbridos) y *Dalea* (22 taxones); y las plantas herbáceas dominan la flora (71.3%). Veintiuna especies de la flora de Yécora tienen protección federal en la NOM-059-SEMARNAT-2010. Las especies introducidas representan el 6.2% de la flora, pero sólo el zacate búfel (*Pennisetum ciliare*) en las partes bajas tropicales y el zacate rosado (*Melinis repens*) en pastizales y encinales son invasoras de hábitats naturales.

La vegetación se divide en zonas de matorral espinoso de piedemonte y selva baja caducifolia en las partes bajas, hasta encinales y bosques de pino encino en las partes altas. La diversidad de la flora aumenta con la altitud y la precipitación, con la mayor riqueza en el bosque de pino encino. La flora de Yécora es típica de la zona Madre Tropical y sirve como referencia para evaluar las afinidades madreñas en las floras del Archipiélago Madre del noreste de Sonora y sureste de Arizona.

## INTRODUCTION

### Sierra Madre Occidental

The Sierra Madre Occidental extends from Zacatecas and Jalisco north to Chihuahua and Sonora in western Mexico (Rzedowski 1978). The Continental Divide follows the Sierra Madre northward to the Sierra Huachinera on the Chihuahua-Sonora border, and then through the isolated Sierra el Pulpito and Sierra San Luis in Sonora and the Animas Mountains in southwestern New Mexico. The Madrean Archipelago is the region of isolated Sky Island mountain ranges between the northern Sierra Madre Occidental in Sonora and Chihuahua and the Mogollon Rim of central Arizona (Lowe 1992; McLaughlin 1995; Warshall 1995; Fig. 1A & B). González-Elizondo et al. (2012) defined the floristic divisions of the Sierra Madre Occidental. The Madrean Tropical zone is on the northwestern crest of the Sierra Madre above tropical vegetation on the Pacific slopes. Floras of the Sky Islands are extensions of both Madrean Tropical and Northern Madrean floristic divisions (González-Elizondo et al. 2012).

Warshall (1995) recognized 40 Sky Island mountain ranges with crowns of oak woodland and pine-oak forest in the Madrean Archipelago based on the Brown and Lowe (1982) vegetation map. A new GIS-based analysis identified 55 Sky Islands and Sky Island complexes of ranges connected by oak woodland corridors in the Madrean Archipelago, 23 in Arizona and New Mexico and 32 in Sonora and Chihuahua (Deyo et al. 2013; Van Devender et al. 2013a).

In this paper, we discuss the Tropical Madrean flora of the Municipio de Yécora in the Sierra Madre Occidental in eastern Sonora in regional floristic and phytogeographic contexts.

## BACKGROUND

### Previous Floristic Studies

Howard Gentry's *Río Mayo Plants* (1942) was a major contribution to the knowledge of the flora of northwestern Mexico. The Río Mayo Region included a broad area in southern Sonora and adjacent Chihuahua in the Ríos Fuerte, Mayo, and Yaqui drainages in both lowland tropical vegetation and upland temperate woodlands and forests of the Sierra Madre Occidental. The completion of Mexico Federal Highway 16 (MEX 16) in 1992 greatly increased access to the northern Sierra Madre Occidental in Sonora and Chihuahua (Búrquez et al. 1992). A revision of the Río Mayo flora by Martin et al. (1998) recorded a total of 2,835 taxa and incorporated the Madrean floras of the Cascada de Basaseáchi (Spellenberg et al. 1996) and Nabogame (Laferrière 1994), Chihuahua.

Stephen S. White of the University of Michigan led three botanical expeditions to explore northeastern Sonora in 1938-1941, (White 1948). His collections in the Sierra El Tigre were the first intensive inventory of a major Sky Island mountain range in Sonora. Fishbein et al. (1995) presented a preliminary flora of the Sierra de los Ajos, a high-elevation range near Cananea.

### History of collections

The Río Mayo Region of Gentry (1942) includes the Yécora area in the Río Yaqui drainage, but difficulty of access prevented him from reaching there. Later, he went to Santa Ana on the southwestern edge of the Mesa del Campanero in November 1958. Richard F. Felger collected in the Yécora area in June 1955 and December 1959. Campbell W. Pennington conducted ethnographic studies of the Mountain Pima Indians in El Kípor and Maycoba east of Yécora in July 1968 (with Timothy Dunnigan) and August 1970. His plant collections are in the University of Texas herbarium in Austin.

Raymond M. Turner and J. Rodney Hastings, coauthors of "An Atlas of Some Plant Distributions in the Sonoran Desert" (Hastings et al. 1972), made Yécora area collections in October 1969; in May 1975 with Annetta Carter, Reid Moran, George Cummins, and G. Culver and also in

August 1985 with Paul S. Martin. Deborah E. Goldberg made extensive collections in the Santa Ana and Santa Rosa areas with Stephen P. McLaughlin and Turner as part of her dissertation on vegetation and flora of hydrothermally-altered soils on gossans in 1975-1977 and 1980 (Goldberg 1982, 1985). In March 1975, Martin led an expedition from the University of Arizona to cross the Sierra Madre Occidental through Yécora to the Cascada de Basaseáchi in Chihuahua. Martin returned to Mesa del Campanero with George M. Ferguson in May 1988, March 1990, and July 1992.

With the completion of MEX 16, which connects Hermosillo, Sonora, and Ciudad Chihuahua, floristic knowledge of the Yécora area and the northwestern Sierra Madre Occidental increased dramatically, and was included in the revised flora in Gentry's *Río Mayo Plants* (Martin et al. 1998). Mark Fishbein, Michelle McMahon, Ferguson, Felger, and Michael F. Wilson collected extensively in the Yécora area in July 1994. Van Devender and Reina-Guerrero began an intensive inventory of the flora of the Municipio de Yécora in 1995 (Reina-G et al. 1999). About 180 botanists have been on collecting trips in the Yécora area. Except for individual species descriptions, our publications on the flora of the Ciénega de Camilo (Van Devender et al. 2003) and the sedges and grasses of the Municipio de Yécora (Roalson et al. 2002; Van Devender et al. 2005) are the first for the Yécora area.

The Madrean Archipelago Biodiversity Assessment (MABA) program was initiated by Sky Island Alliance in 2009 to accumulate biological records from the Sky Islands Region in Sonora and Chihuahua. The Madrean Discovery Expeditions (MDE) program at GreaterGood.org was created in 2015 to continue biotic inventories in the Madrean Archipelago. There were nine expeditions to Sonoran Sky Islands where large groups of biologists documented animals and plants, plus smaller inventory trips to ten additional mountain ranges. A preliminary flora of the Sierra Bacadéhuachi was based on inventories on four trips in 2011-2012 (Van Devender et al. 2013b). This range, located 165 km north of the Yécora area, has been considered either a southern Sky Island or a western extension of the Sierra Madre Occidental. All of these records from MABA and MDE inventories and many high-resolution images are publicly available in the MABA ([madrean.org](http://madrean.org)) and MDE ([madreandiscovery.org](http://madreandiscovery.org)) databases for use in conservation, research, and education. The FLORA parts of these databases are directly linked to the Southwest Environmental Information Network (SEINet, [swbiodiversity.org/seinet/](http://swbiodiversity.org/seinet/)), which contains locality information on 4.2 million regional herbarium specimens and 802,000 images from the southwestern USA and northwestern Mexico.

### **Study Area and Inventories**

MEX 16 provides an elevational transect through the Municipio de Yécora from lowland tropical vegetation to highland montane forests (Fig. 2A & B). The Municipio is an area of 3,300 km<sup>2</sup>. Most of the Municipio is in the Río Yaqui drainage; only the southeastern edge of Mesa del Campanero is in the Río Mayo watershed. Elevation in the Municipio ranges from 480 m along Arroyo Tepoca near Curea to 2,150 m on Mesa del Campanero, an increase of 1,770 meters in 27 kilometers (by air). Regional base level is 160 m elevation along the Río Yaqui at Ónavas west of the Municipio de Yécora.

Between May 1995 and August 2008, and again in August 2012, we visited the Yécora area 36 times in all seasons. The flora is based on 8100 plant collections (6567 by Van Devender and Reina-G). Label information for most of the collections is available online in the MABA/SEINet databases. Specimens were deposited into herbaria at the University of Arizona (ARIZ), Universidad de Sonora (USON), Universidad Nacional Autónoma de México (MEXU), Arizona State University (ASU), New Mexico State University (NMC), Centro de Investigaciones Biológicas del Noroeste (HCIB), University of Texas (TEX), Missouri Botanical Garden (MO), Rancho Santa Ana Botanical Garden (RSA), Instituto de Ecología del Bajío (IEB), and others.

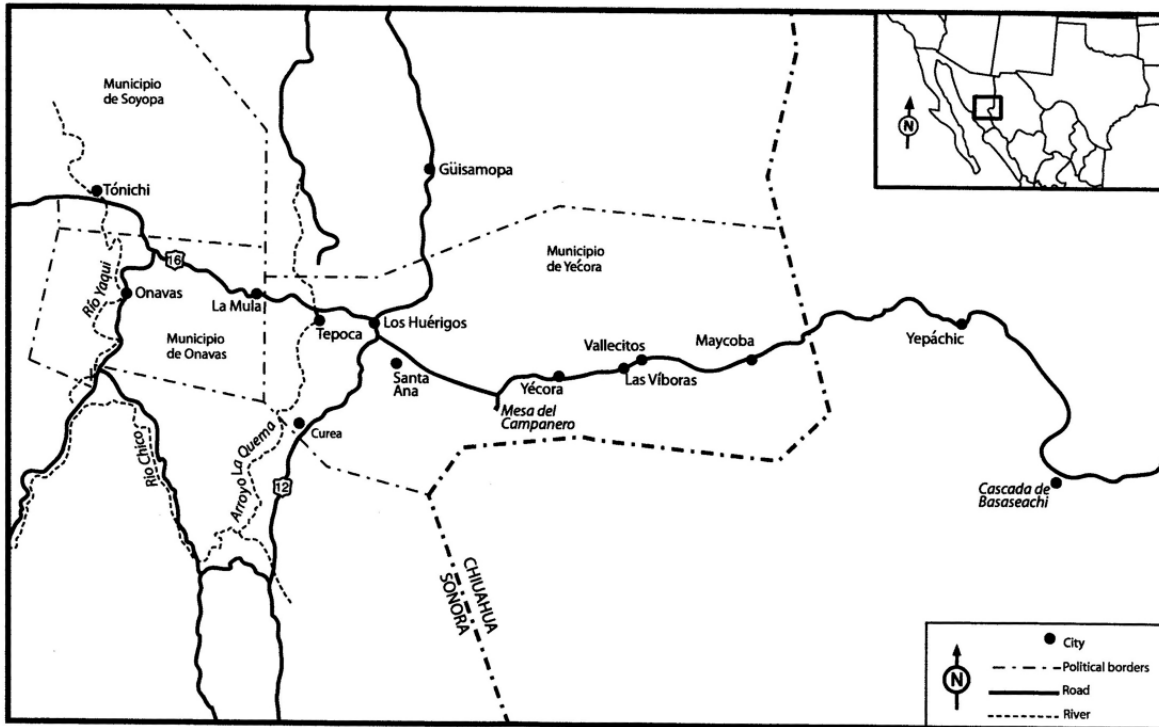


Figure 1A. Map of Sonora and the Yécora region by Gerald Dawavendewa.

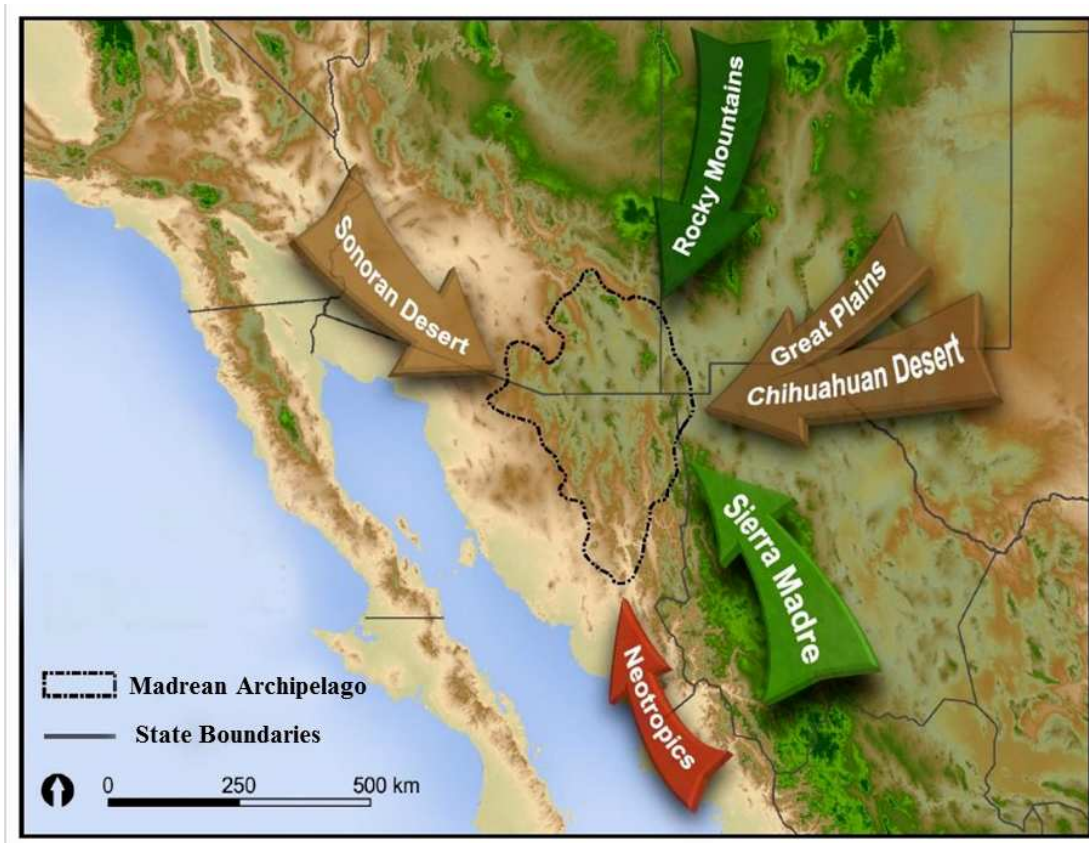


Figure 1B. Map of the convergence zone of five biotic provinces in the Madrean Archipelago. Map by Nick Deyo, Sky Jacobs, and Van Devender.

## Floristic Analyses

The Yécora flora has a total of 1777 taxa in 150 families and 687 genera. The families with the most species are Asteraceae (257 taxa, 14.5% of the flora), Poaceae (200 taxa, 11.3%), and Fabaceae (188 taxa, 10.6%). The grasses were summarized in Van Devender et al. (2005). These families plus 14 others with 20 or more taxa (Table 1) make up 65.3% of the flora. Asteraceae, Poaceae, and Fabaceae are typically the most important families in North American floras, with Fabaceae dominant in tropical deciduous forest. In the Municipio de Yécora, the numbers of species of Asteraceae and Poaceae increase with elevation in more temperate areas. Ferns and allied plants are diverse with 15 families, 31 genera, and 78 taxa (4.4%; Yatskievych et al. 2010). The importance of Euphorbiaceae (3.2%), Convolvulaceae (2.5%), Solanaceae (2.5%), Malvaceae (2.1%), Rubiaceae (1.8%), Apocynaceae (including Asclepiadaceae, 1.7%), and Orchidaceae (1.5%) in the flora reflects the influence of the New World tropics.

*Muhlenbergia* (38 taxa), *Euphorbia* (31 taxa), *Cyperus* (29 taxa), *Ipomoea* (26 taxa), *Quercus* (23 taxa including 7 hybrids), and *Dalea* (22 taxa) are especially diverse genera. These genera plus eleven others with 11 or more taxa represent 18.2% of the flora. With eleven species, *Pinus* is relatively diverse.

Plant nomenclature follows Gentry's Río Mayo Plants (Martin et al. 1998), the flora of Sonora appendix in Van Devender et al. (2010), the Taxonomic Thesaurus in SEINet (<http://swbiodiversity.org/portal/index.php>), and personal choices. Names, synonyms, and authors were checked in Missouri Botanical Garden's Tropicos taxonomic website (<http://www.tropicos.org/>).

**Life forms.** The Yécora flora has a wide range of life forms (Table 2). Woody plants, including shrubs (8.9% of the flora), trees (7.5%), subshrubs (4.4%), woody vines (1.8%), and woody parasites (0.4%) make up 23.1% of the flora. The vegetation of the Municipio de Yécora, with the exception of montane grasslands, is dominated by trees, which are relatively minor components in the flora. Succulents including cacti and *Agave* and its relatives account for 2.5% of the flora. The majority (71.3%) of the plants in the flora are herbs, with more perennials (43.9%) than annuals (27.4%). The importance of annual dicots in the Yécora flora is relatively low (338 taxa, 19.0%) compared to Mohave Desert floras in California and Sonoran Desert floras in southwestern Arizona and northwestern Sonora, where annual dicots comprise 40-50% of local floras. Moreover only 13.3% of the annual dicots are obligatory winter-spring species, reflecting the distance from the North Pacific Ocean and decreasing importance of rainfall from winter frontal storms. Grasses and sedges account for 14.5% of the flora, with more perennials (9.0%) than annuals (5.5%). Ferns and their relatives are common herbs (4.4%). Aquatic herbs (0.6%) are both perennial and annual as are parasitic plants (0.8%). Vines are common (6.1%) in the flora and include woody lianas, herbaceous perennials, and annuals, especially *Ipomoea* (1.5%).

**Non-native species.** A total of 111 taxa (6.2%) in the Yécora flora is introduced from elsewhere. Non-natives are most common in the Poaceae (31 taxa), Brassicaceae (7 taxa), Asteraceae (6 taxa), and Fabaceae (5 taxa). The percentages of non-natives is very low in all habitats, reflecting low levels of disturbance, i.e., foothills thornscrub (1.2%), tropical deciduous forest (3.0%), oak woodland (2.2%), grassland (0.9%), and pine-oak forest (3.5%). Non-natives often follow roadways or are most common near houses and in gardens. The higher numbers of non-natives in tropical deciduous forest and pine-oak forest partially reflects the locations of the main settlements in those areas.

Most non-native species are not invasive with little impact on native species or vegetation. Mustards are widespread in the study area but not dense in any area. The only invasive species in the Municipio de Yécora are buffelgrass/*zacate búfel* (*Pennisetum ciliare*) in the tropical lowlands and Natal grass/*zacate rosado* (*Melinis repens*) in grassland and oak woodland. Hindi grass (*Dichanthium*

*annulatum*) is a common invasive in the Álamos area that recently was introduced into Arizona (Felger et al. 2005). It is only present in a few areas in tropical deciduous forest in the Municipio de Yécora but is potentially invasive in tropical lowland vegetation.

Non-natives that are widespread but not invasive include Bermuda grass/zacate inglés (*Cynodon dactylon*), black mustard/mostaza (*Brassica nigra*), and London rocket/pamitón (*Sisymbrium irio*). South American tree tobacco/juan loco (*Nicotiana glauca*) is not common but occurs as high as 1900 m elevation in pine-oak forest at Puerto de la Cruz. Castor bean/higuerilla (*Ricinus communis*) is occasional in the tropical lowlands but is invasive in other areas in Sonora (Van Devender et al. 2009). Today it is widespread in Sonora, especially in warmer areas, but Gentry (1942) did not report it from the Río Mayo Region.

A cultivated tobacco with pink flowers called *papante* (*Nicotiana tabacum*) is well established in the Mountain Pima Indian village of El Kípor. Chinaberry tree/*piocha* (*Melia azederach*) was formerly used as an ornamental tree in lowland towns. It is now established in tropical riparian forests near Curea, La Quema, San Nicolás, and Santa Rosa, and in montane forests along MEX 16 near Maycoba and Yécora. Peach/*durazno* (*Prunus persica*) following MEX 16 westward from Chihuahua has reached Puerto de la Cruz west of Yécora.

Lantana/*confituría negra* (*Lantana camara*) with orange and red flowers is native to the tropical lowlands in the Municipio, but a cultivar (*L. camara* var. “*mozelle*”) with pink and yellow flowers was encountered in pine-oak forest along MEX 16 west of Yécora.

Neither species of tamarisk/*pino salado* (*Tamarix aphylla*, *T. chinensis*) are common in the Municipio, although they are invasive in other parts of Sonora (Van Devender et. al. 2009).

## Vegetation

**Vegetation zonation.** There are important changes in vegetation with elevation that are most easily seen along MEX 16 from Tepoca to the Chihuahua border (Fig. 2A). The transition between the New World tropics and the northern temperate zone is at about 29°N in east-central Sonora. Foothills thornscrub (*matorral espinoso*) is a very important biotic community in Sonora that is transitional between Sonoran desertscrub and tropical deciduous forest in southern Sonora and oak woodland in eastern Sonora (Van Devender et al. 2013c). In the Municipio de Yécora, thornscrub only occurs in a limited area at 460-550 m elevation in a rain-shadow valley at Curea (Fig. 3A). Dominants include *tepeguaje* (*Lysiloma watsonii*), *torotes* (*Bursera fagaroides* var. *elongata*, *B. laxiflora*), *papelío* (*Jatropha cordata*), *palo chino* (*Havardia mexicana*), tree morning glory/*palo blanco* (*Ipomoea arborescens*), tree ocotillo/*ocotillo macho* (*Fouquieria macdougalii*), organpipe cactus/*pitahaya* (*Stenocereus thurberi*), and tropical cholla/*siviri* (*Cylindropuntia thurberi*).

In the Municipio, tropical deciduous forest (*selva baja caducifolia*) is found in a broad band at 500-1160 m elevation. Dominants include most of the same species in foothills thornscrub plus *mauto* (*Lysiloma divaricatum*), *torotes* (4 additional species), figs/*higueras* (5 species), *amapa morada* (*Tabebuia impetiginosa*), kapok/*pochote* (*Ceiba acuminata*), *palo zorillo* (*Senna atomaria*), and *etcho* (*Pachycereus pecten-aboriginum*; Fig. 3B). Two oaks, including Chihuahua oak/*куси peludo* (*Quercus chihuahuensis*) and *encino* (*Q. tuberculata*), occur locally in tropical deciduous forest.

In the Yécora area, oak woodland (*encinal*) is present at 1050-1700 m elevation. Dominants include oaks (*Quercus arizonica*, *Q. oblongifolia*, plus 8 other species, and 5 interspecific hybrids), Chihuahua pine/*pino chino* (*Pinus chihuahuana*), and alligator juniper/*táscate* (*Juniperus deppeana*). At 1220-2240 m, oak woodland often occurs in a mosaic with pine-oak forest (*bosque de pino encino* Fig. 4A). Pine-oak forest dominants include most of the same trees as oak woodland plus additional



Figure 2A. Highway MEX 16 was finished in 1992. Photo by Erik F. Enderson.



Figure 2B. Mesa del Campanero. Photo by Erik F. Enderson.



Figure 3A. Foothills thornscrub near Curea. Photo by Van Devender.





Figure 3B. Tropical deciduous forest near Santa Ana. Photo by Mark A. Dimmitt.



Figure 4A. Oak woodland near Los Pilares. Photos by Van Devender.



Figure 4B. Pine-oak forest near Yécora. Photo by Erik F. Enderson.

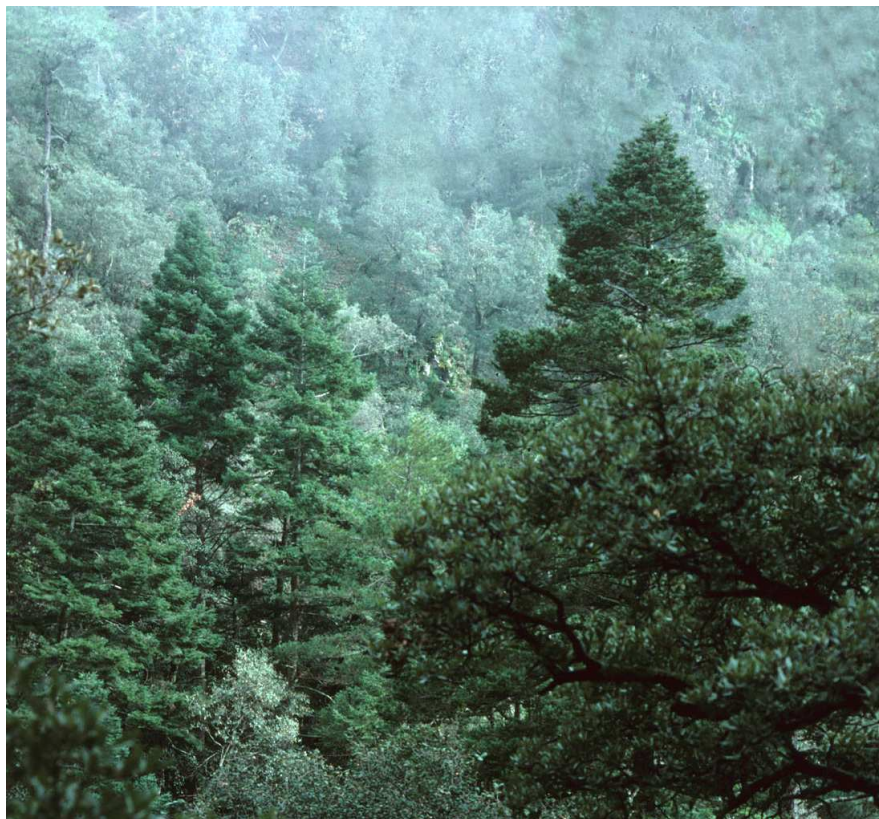


Figure 5A. Mixed-conifer forest in Barranca el Salto on Mesa del Campanero. Photo by George M. Ferguson.

pinos (*P. arizonica*, *P. engelmannii*, *P. yecorensis*, plus 6 other species) and Arizona madrone/madroño (*Arbutus arizonica*; Fig. 4B). High elevation pine-oak species include southwestern white pine/piñón (*P. strobiformis*), oaks (*Q. durifolia*, *Q. jonesii*, and *Q. mcvaughii*), and madroño (*A. xalapensis*). Mixed-conifer forest (*bosque de coníferas mixtas*) with Durango fir/pinabete duranguense (*Abies durangensis*) restricted to Barranca El Salto and two other areas on Mesa del Campanero at 1900-2100 m are the only examples of that vegetation type in Sonora (Fig. 5A & B).



Figure 5B. Durango fir (*Abies durangensis*). Photo by George M. Ferguson.

Grassland (*pastizal*) occurs in high valleys at 1200-1700 m, often in a mosaic with oak woodland or pine-oak forest. Grassland also occurs in the broad Yécora Valley. The Yécora grassland is dominated by a diverse mixture of native perennial herbs, including grasses (42 species) and composites (56 species).

**Special habitats.** Riparian areas bisect all other vegetation types in the Municipio. Dominant riparian trees in tropical vegetation include *guásima* (*Guazuma ulmifolia*) and willows/*saucos* (*Salix bonplandiana*, *S. goodingii*, *S. taxifolia*). Mexican bald cypress/*sabino* (*Taxodium distichum* var. *mexicanum*) is at Tepoca. Velvet ash/*fresno* (*Fraxinus velutina*), Arizona walnut/*nogal* (*Juglans major*), and *sabino* (*Juniperus blancoi* var. *mucronata*) are locally common riparian trees in oak woodland. Arizona alder/*alamillo* (*Alnus oblongifolia*), bigtooth maple/*haya* (*Acer grandidentatum*), Gentry cherry (*Prunus gentryi*), and Mexican white cedar/*sabino* (*Cupressus lindleyi*) are locally common in pine-oak forest riparian canyons, while hophornbeam/*palo prieto* (*Ostrya virginiana*) and Mexican basswood (*Tilia americana* var. *mexicana*), and Mexican hollies (*Ilex rubra*, *I. toluhana*) are rare. Wetlands include the Ciénega de Camilo, a peat/*musgo* (*Sphagnum palustre*) spring mound in a riparian canyon in pine-oak forest 1550 m elevation at east of Maycoba (Van Devender et al. 2003; Fig. 6A). There are marshy wetlands on the south edge of Yécora that are disappearing as the town expands.



Figure 6A. *Sphagnum palustre* in the Ciénega de Camilo east of Maycoba. Photo by Doug Danforth.



Figure 6B. Barren areas near Yécora on the volcanic mudflow deposits of the Baucarit Formation. Photo by Van Devender.

Volcanic mudflow deposits of the Báucarit Formation form barrens near Yécora (Fig. 6B). This is a very unusual habitat that supports widely scattered oaks and pines or no woody plants at all, even though 913 mean annual mm/yr rainfall (Búrquez et al. 1992) is adequate to support pine-oak forest. Mudflow deposits intercalated between volcanic rocks in the Yécora area were deposited in the middle Miocene age (17.0-17.6 mya, million years ago; Cochemé & Demant 1991) at the beginning of the tectonism that transformed northwestern Mexico, including the Yécora Valley, and the southwestern USA into the modern Basin and Range Province (Cochemé & Demant 1991). The mudflow surfaces in the Yécora Valley likely formed later in the Miocene (R. Scarborough, pers. comm., 1998). From July through September, heavy rainfall keeps the mudflow surfaces wet and a diverse dwarf herb flora flourishes including sedges (10 species in 7 genera), succulents (*Agave polianthiflora*, *Echinocereus stoloniferus* var. *tayopensis*, *Mammillaria wrightii* var. *wilcoxii*, *Phemeranthus marginatus*, and *Sedum vinicolor*), grasses (*Microchloa kunthii*, *Muhlenbergia annua*, *M. shepherdii*, and *M. texana*), legumes (*Aeschynomene americana* var. *glandulosa*, *Dalea confusa*, *D. filiformis*, and *Stylosanthes humilis*), and six endemic plants (see below).

Another unusual habitat in the Municipio de Yécora is the gossans, hydrothermally-altered volcanic areas with bright red or yellow acidic soils (pH as low as 4, Fig. 7A). Islands of open pine-oak forest or oak woodland are surrounded by tropical deciduous forest (Goldberg 1982, 1985). Notable low elevation stands of montane trees include Chihuahua oak at 650 m on volcanic soils near La Concepción; Yécora pine/*pino colorado* (*Pinus yecorensis*), and Chihuahua and willowleaf/*cusi* (*Quercus albocincta*; Fig. 7B) oaks at 900 m elevation at Agua Amarilla; Chihuahua pine, Chihuahua

oak, and encino at 820 m west of Santa Ana; eggcone pine/*pino chomonqui* (*P. oocarpa*) at about 1000 m between San Nicolás and the turn off to Santa Ana; stripbark alligator juniper/*táscate* (*Juniperus deppeana* var. *patoniana*) at 900 m north of San Nicolás; and hand basin oak/*güeja* (*Q. tarahumara*) at 1020 m near Santa Rosa.



Figure 7A. Gossan at Agua Amarilla west of Tepoca. Photo by Van Devender.



Figure 7B. *Cusi* (*Quercus albocincta*) from Cerros Colorado near Álamos. Photo by Van Devender.

## DISCUSSION

The largest area of Tropical Madrean forests is in the northwestern Sierra Madre Occidental from Yécora to the Huachinera area in eastern Sonora. The flora of the Municipio de Yécora with 1777 taxa is very diverse. It serves both to characterize Madrean Tropical floristic division of the Sierra Madre Occidental, and as a baseline to evaluate the Madrean contribution to Sky Island floras in the Madrean Archipelago (Reina-G. and Van Devender 2005; Van Devender et al. 2013a, b).

### Madrean Archipelago flora

McLaughlin (1995) estimated the number of plants in 12 mountain ranges in southeastern Arizona to be 627 species per flora on average, with 33-50% of the regional flora in each of the larger ranges. He estimated 2100 species occur in the Sky Island Region of southeastern Arizona, or 42.1% of the 4212 taxa documented in SEINet for Arizona (Lesley Landrum, pers. comm. 2013). McLaughlin (1995) estimated 2300 to 2800 plant taxa for the entire Sky Island Region, but the total is probably higher because plant species diversity increases southward in New World tropical vegetation and in the Sierra Madre Occidental.

The flora of the state of Sonora with an area of 184,934 km<sup>2</sup> presently includes 3790 species and infraspecific taxa documented by herbarium specimens (Van Devender et al. 2015, unpublished data). Considering that plant species diversity is highest in Sonora in tropical deciduous forest and Madrean woodlands and forests, perhaps 60-70% of the state flora occurs in the eastern third of the state. The Yécora flora with 1777 taxa makes up more than half of the Madrean Archipelago flora and 46.9% of the Sonoran flora.

### Species diversity gradient

Diversity in the Yécora flora increases with elevation; i.e. 313 taxa in foothills thornscrub, 795 taxa in tropical deciduous forest, 839 taxa in oak woodland, and 1121 taxa in pine-oak forest. Several factors influence these numbers. The area of foothills thornscrub is limited to a small area around Curea. West of the Municipio, thornscrub is widespread, supporting many additional species (Van Devender et al. 2013c). Grassland in the Yécora area only has 328 taxa, reflecting its secondary role as openings in oak woodland and pine-oak forest.

MEX 16 is a dispersal corridor for species in the Municipio de Yécora. The Mountain Pima Indians said that willow ragwort/*ruina* (*Barkleyanthus salicifolius*) was not in El Kípor prior to the construction of MEX 16, but has moved from Chihuahua as far west as Puerto de la Cruz west of Yécora. Tropical species move to higher elevations into Madrean vegetation during warmer periods. Examples include boatthorn acacia/*güinolo* (*Acacia cochliacantha*) at 1700-1720 m elevation in pine-oak forest west of Puerto de la Cruz and at Barranca Honda, and sweet acacia/*vinorama* (*A. farnesiana*) at 1700-1820 m elevation on the north slopes of Mesa el Campanero. However, the extreme freeze of February 2011 likely killed most of these lowland plants.

### Endemism

Between 1977 and 2014, 29 plant taxa were described from the Municipio de Yécora (Table 3), 20 of them based on collections from this study. Fourteen species are endemic to the Municipio, including *Dalea analiliana*, *Echinocereus laui*, *Erigeron reinana*, and *Stevia reinana*. Other new species such as *Boerhavia traubae*, *Mammillaria saboae* var. *haudeana*, *Menodora yecorana*, *Pectis vandevenderi*, *Portulaca yecorensis*, and *Tridax yecorana* are restricted to the Báucarit Formation mudflow barrens. *Eleocharis yecorensis* was described from the marshy wetlands near Yécora (Roalson 1999), but was later determined to have a wider distribution in the Sierra Madre Occidental (M.S. González-E., pers. comm. 2000).

Although the rhetoric commonly used in Arizona describes the Sky Island mountain ranges as evolutionary arenas for speciation, their floras differ from true insular floras in high species diversity,

low local and regional endemism, and low percentages of non-native species (McLaughlin 1995). New species are discovered much more often in the Yécora area in the mainland Sierra Madre Occidental than in any of the Sky Islands.

### Protected species

Twenty-one species in the Yécora flora are legally protected by the Mexican government in the Norma Oficial Mexicana, NOM-059-SEMARNAT-2010 (Diario Oficial de la Federación 2010; Table 4). *Litsea glaucescens* var. *subsolitaria* and *Tilia americana* var. *mexicana* have Peligro (P, endangered) status. Seven species are Amenazada (A, threatened): *Agave parviflora* subsp. *densiflora*, *A. polianthiflora*, *Echinocereus lauii*, *Juglans major*, *Tabebuia chrysantha*, *T. impetiginosa* (as *T. palmeri*), and *Trifolium wormskjoldii* var. *ortegae*. Twelve other species are Protegida (Pr, special protection).

### Biogeography

The oak woodlands and pine-oak forests are very similar in appearance in the Madrean Tropical Sierra Madre Occidental and the Sky Island mountain ranges throughout the Madrean Archipelago, reflecting widespread dominant trees and shrubs. Reina-G. & Van Devender (2005) compared the floras of the Yécora area and the Huachuca Mountains, one of the most diverse Sky Island ranges in Arizona (Bowers & McLaughlin 1996). But only 40% or less of the Sky Island floras actually occur in the mainland Sierra Madre Occidental as temperate and desert plants increase in importance northward. The Yécora flora is about 30% richer than any Sky Island.

The Madrean Archipelago is a convergence zone for five biotic provinces (Van Devender et al. 2013a; Fig. 1B), i.e., the cold temperate Rocky Mountains and Colorado Plateaus to the north, the Great Plains grasslands/Chihuahuan desertscrub to the east, Sonoran desertscrub to the west, and Neotropical vegetation and Sierra Madre Occidental tropical temperate forests to the south. On the west side of North America, the transition between the New World tropics and the northern temperate zone is at about 29°N in east-central Sonora. Tropical deciduous forest is (or was formerly) widespread along the Pacific coast from Costa Rica northwest to the Sierra San Javier (28°35'N), west of the Río Yaqui 80 km west-northwest of Yécora (Van Devender et al. 2010). The northern limits of thornscrub are at about 30°30'N in the Ríos Bavispe and Sonora valleys (Van Devender 2013c), but quite a few thornscrub plants cross the border into southern Arizona in desert grassland or oak woodland.

In contrast, the main influences on the Yécora area are the Neotropics and the Sierra Madre Occidental. Northern cold temperate species are rare, but include bracken fern/*seri* (*Pteridium aquilinum*) and striped wintergreen (*Chimaphila maculata*). Northern grassland elements include calabacilla de burro (*Apodanthera undulata*) and pink throat morning glory/*trompillo rastrero* (*Ipomoea longifolia*). The absence of species from other biotic province is more than offset by increasing diversity to the south in both lowland and montane biotic communities. This is primarily related to warmer winter temperatures and reduced frequencies of hard freezes. Desert grassland, which is widespread in the southwestern USA and northeastern Sonora, supports a moderately diverse flora (McClaran & Van Devender 1995), but is not present in the Yécora area. The southernmost remnant desert grassland occurs in the Sierra de Bacadéhuachi (29°45'N, Van Devender et al. 2013b), 165 km north of Yécora. In the Arizona Sky Islands, the maximum species diversity is in the middle elevations in the desert grassland-oak woodland ecotone and lowest in the high elevation pine-oak forests. However, Rzedowski (1978) found that in the Sierra Madre Occidental in Mexico the highest species diversity is in pine-oak forest, as it is in the Yécora area.

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**Table 1. Important families and genera in the Yécora flora.**

**Families** (17 families – 1161 taxa [65.3%])

Asteraceae - (257 taxa, 14.5% of the flora)  
 Poaceae – 200 taxa (11.3%)  
 Fabaceae – 188 taxa (10.6%)  
 Cyperaceae – 61 taxa (3.4%)  
 Euphorbiaceae – 57 taxa (3.2%)  
 Convolvulaceae - 45 taxa (2.5%)  
 Solanaceae – 45 taxa (2.5%)  
 Scrophulariaceae – 43 taxa (2.4%)  
 Lamiaceae – 40 taxa (2.2%)  
 Malvaceae 37 - taxa (2.1%)  
 Pteridaceae – 35 taxa (2.0 %)  
 Rubiaceae – 32 taxa (1.8%)  
 Orchidaceae – 27 (1.5%)  
 Asclepiadaceae – 26 (1.5%) (+ 5 taxa Apocynaceae = 31 taxa [1.7%])  
 Cactaceae – 25 taxa (1.4%)  
 Brassicaceae – 23 taxa (1.3%)  
 Onaceaceae – 20 taxa (1.1%)

**Genera** (17 genera – 324 taxa [18.2%])

*Muhlenbergia* – 38 taxa (2.1%)  
*Euphorbia* – 31 taxa (1.7%)  
*Cyperus* – 29 (1.6%)  
*Ipomoea* – 26 taxa (1.5%)  
*Quercus* – 23 (1.3%, 7 hybrids)  
*Dalea* – 22 taxa (1.2%)  
*Brickellia* – 16 taxa (0.9%)  
*Cheilanthes* – 15 taxa (0.8%)  
*Erigeron* – 15 taxa (0.8%)  
*Salvia* – 15 taxa (0.8%)  
*Solanum* – 15 taxa (0.8%)  
*Stevia* – 15 taxa (0.8%)  
*Bidens* – 14 taxa (0.8%)  
*Physalis* – 14 taxa (0.8%)  
*Paspalum* – 13 taxa (0.7%)  
*Pseudognaphalium* – 12 taxa (0.7%)  
*Pinus* – 11 taxa (0.6%)

**Table 2. Life forms in the Yécora flora (1777 taxa).**

Life Form	# taxa	% taxa
Trees	133	7.5
Shrubs	159	8.9
Subshrubs	78	4.4
Woody vines	32	1.8
Woody parasites	8	0.4
Stem succulents	26	1.5
Rosette succulents	19	1.1
Ferns and allies	78	4.4
Perennial dicot herbs	495	27.8

Epiphytes	4	0.2
Herbaceous perennial vines	42	2.4
Herbaceous perennial parasites	2	0.1
Perennial grasses/sedges	160	9.0
Annual grasses/sedges	98	5.5
Annual dicots	338	19.0
Annual parasites	5	0.3
Annual vines	35	2.0
Aquatic herbs	11	0.6

Total woody plants: 410 (23.1%)

Total succulents: 45 (2.5%)

Total herbs: 1268 (71.3%)

Total perennial herbs: 781 (43.9)

Total annual herbs: 487 (27.4%)

Total grasses/sedges: 258 (14.5%)

Total vines: 109 (6.1%)

Total parasites: 15 (0.8)

**Table 3. Taxa described from the Municipio de Yécora. \* = endemic to Municipio.**

1. *Dalea pinetorum* Gentry var. *pinetorum* - Barneby (1977)
2. \**Echinocereus laui* G.R.W. Frank - 1978
3. \**Mammillaria saboae* var. *haudeana* (Lau & Wagner) Glass & R. Foster - 1979
4. \**Ageratina yecorana* B.L. Turner - 1987
5. \**Arceuthobium yecorensis* Hawksworth & Wiens - 1989
6. *Hymenocallis pimana* Laferrière - 1990
7. \**Pectis vandevenderi* B.L. Turner - 1995
8. *Pinus yecorensis* Debreczy & Rácz - 1995
9. \**Tridax yecorana* B.L. Turner - 1995
10. *Euphorbia pionsperma* V.W. Steinm. & Felger - 1997
11. \**Menodora yecorana* T. Van Devender & B.L. Turner - 1997
12. *Mimulus yecorensis* Vickery - 1997 (now *Erythranthe pallens* (Greene) Nesom)
13. *Dasyilirion gentryi* Bogler - 1998
14. \**Erigeron reinana* G.L. Nesom - 1998
15. *Hymenocallis clivorum* Laferrière - 1998
16. *Boerhavia traubae* Spellenb. - 1999
17. *Eleocharis yecorensis* E.H. Roalson - 1999
18. \**Portulaca yecorensis* Henrickson & T. Van Devender - 1999
19. *Juniperus mucronata* R.P. Adams - 2000 [now *J. blancoi* Martínez var. *mucronata* (R.P. Adams) Farjon]
20. *Polypodium praetermissum* Mickel & Tejero - 2004
21. *Woodsia cystopteroides* Windham & Mickel - 2004
22. \**Dalea analiliana* Spellenberg - 2007
23. \**Agave parviflora* Torr. subsp. *densiflora* G. Starr & T.R. Van Devender - 2011
24. *Brickellia enigmatica* B.L. Turner - 2011
25. \**Lepechinia yecorana* Henrickson, Fishbein, and T. R. Van Devender - 2011
26. \**Adenophyllum yecoranum* B.L. Turner - 2013
27. \**Stevia reinana* B.L. Turner - 2013
28. *Astragalus martinii* Spellenb., T. R. Van Devender & P. D. Jenkins - 2014
29. *Quercus barrancana* Spellenb. - 2014

**Table 4. Species in the Yécora flora protected in the Norma Oficial Mexicana, NOM-059-SEMARNAT-2010 (Diario Oficial de la Federación 2010). P: in danger of extinction, A: threatened, and Pr: special protection.**

Family	Species	Category
Agavaceae	<i>Agave parviflora</i> Torr. subsp. <i>densiflora</i> G. Starr & T.R. Van Devender	A
Agavaceae	<i>Agave polianthiflora</i> Gentry	A
Agavaceae	<i>Yucca grandiflora</i> Gentry	Pr
Arecaceae	<i>Brahea nitida</i> Andre	Pr
Betulaceae	<i>Ostrya virginiana</i> (Mill.) Koch.	Pr
Bignoniaceae	<i>Tabebuia chrysantha</i> (Jacq.) G. Nicholson subsp. <i>chrysantha</i>	A
Bignoniaceae	<i>Tabebuia impetiginosa</i> (Mart.) Standl. [ <i>T. palmeri</i> Rose]	A
Bixaceae	<i>Amoreuxia palmatifida</i> Moc. & Sessé	Pr
Cactaceae	<i>Echinocereus lauii</i> G.R.W. Frank	A
Cactaceae	<i>Echinocereus stoloniferus</i> W.T. Marshall var. <i>tayopensis</i> (W.T. Marshall) N.P. Taylor	Pr
Cactaceae	<i>Mammillaria saboae</i> Glass var. <i>haudeana</i> (A.B. Lau & K. Wagner) Glass & R.C. Foster	Pr
Cupressaceae	<i>Cupressus lusitanica</i> Mill.	Pr
Fabaceae	<i>Trifolium wormskioldii</i> Lehm. var. <i>ortegae</i> (Greene) Barneby	A
Juglandaceae	<i>Juglans major</i> (Torr.) A. Heller	A
Lauraceae	<i>Litsea glaucescens</i> Kunth var. <i>subsolitaria</i> (Meissn.) Hemsl.	P
Malvaceae	<i>Tilia americana</i> L. var. <i>mexicana</i> (Schltdl.) Hardin	P
Melanthiaceae	<i>Anticlea virescens</i> (Kunth) Rydb. [ <i>Zigadenus virescens</i> (Kunth) J.F. Macbr.]	Pr
Poaceae	<i>Tripsacum zopilotense</i> Hernandez X. & Randolph	Pr
Rubiaceae	<i>Crusea coronata</i> B.L. Rob. & Greenm.	Pr
Rubiaceae	<i>Crusea hispida</i> (Mill.) B.L. Rob. var. <i>hispida</i>	Pr
Zygophyllaceae	<i>Guaiacum coulteri</i> A. Gray	Pr