Revista Mexicana de Ciencias Forestales Vol. 10 (56)
Noviembre –Diciembre (2019)

DOI: https://doi.org/10.29298/rmcf.v10i56.479

Review article

Revisión sobre la distribución y conservación de *Taxus globosa* Schltdl. (Taxaceae) en México

Review on the distribution and conservation of *Taxus globosa* Schltdl. (Taxaceae) in Mexico

Liliana Muñoz-Gutiérrez[1]*, Susana E. Ramírez-Sánchez[2] y Mario Valerio Velasco-García[1]

Resumen

Taxus globosa es una conífera poco estudiada desde el punto de vista biológico, ecológico y reproductivo. Importante por la sustancia química que produce llamada taxol, útil en el tratamiento de cáncer de ovario y de mama, principalmente. En México está catalogada como especie Sujeta a Protección Especial en la Norma Oficial Mexicana NOM-059-SEMARNAT-2010, lo que implica que podría estar amenazada por factores negativos que inciden en su distribución, desarrollo y regeneración. En el ámbito internacional, se incluye en la lista roja de especies amenazadas de la Unión Internacional para la Conservación de la Naturaleza (UICN) como especie en peligro de extinción. Por lo anterior, es necesario conocer la situación que guardan las poblaciones naturales en su intervalo de distribución natural y comprender sus mecanismos de regeneración y propagación, para el desarrollo de tecnologías que permitan su domesticación y producción. En la presente revisión se recopiló la información existente acerca de *T. globosa* en México, se expone la distribución actual y potencial; además de revisar las condiciones de las poblaciones en cuanto a la asociación con otras especies vegetales, densidad de individuos adultos y juveniles, aspectos de regeneración, y en consecuencia del estado de conservación de las poblaciones. Con la finalidad de identificar líneas de investigación particulares de este recurso forestal que contribuyan a su conservación y aprovechamiento sustentable.

Palabras clave: Conservación, distribución natural, distribución potencial, ecología, reproducción, *Taxus globosa* Schltdl.

Abstract

Taxus globosa is a conifer that has been little studied from the biological, ecological and reproductive point of view. It produces a pseudo-alkaloid called *taxol*, which acts against various types of cancer, including ovarian and breast cancer. In Mexico, this species is cataloged under special protection in the Mexican Official Norm NOM-059-SEMARNAT-2010, which implies that it could be threatened by negative factors that affect its distribution, development and regeneration. At the international level, it is included in the red list of the International Union for Conservation of Nature (UICN) as an endangered species. Therefore, it is necessary to know the range of distribution of the natural populations and understand their mechanisms of regeneration and propagation in order to develop technologies that will allow their domestication and production. The present review has compiled the bibliographic information on *T. globosa* and its current and potential distribution, and reviews the conditions of the populations, the association with other plant species, the number of juvenile and adult individuals, and aspects related to their regeneration and their conservation status, in order to identify the research lines of this forest resource, which contributes to the conservation and sustainable use of this species.

Key words: Conservation, natural distribution, potential distribution, ecology, reproduction, *Taxus globosa* Schltdl.

Fecha de recepción/Reception date: 16 de diciembre de 2018
Fecha de aceptación/Acceptance date: 5 de julio de 2019

[1]Centro Nacional de Investigación Disciplinaria en Conservación y Mejoramiento de Ecosistemas Forestales, INIFAP. México.
[2]Departamento de Producción Agrícola y Animal Universidad Autónoma Metropolitana. México.
*Autor por correspondencia: gutierrez.liliana@inifap.gob.mx

Introduction

Taxus globosa Schltdl. belongs to the Taxaceae family (Cope, 1998); it is an evergreen dioic conifer that reproduces through seeds (Zavala, 2001). This small, slowly-growing tree species, usually between 6 and 10 meters tall and with normal diameters of 30 to 40 cm (Shemluck *et al*., 2003), produces taxol, a substance that is useful in the treatment of various types of cancer, including cervical and breast cancer (Hansen *et al*., 1994; Soto *et al*., 2000; Zavala, 2001; Shemluck *et al*., 2003; Barrales-Cureño and Soto-Hernández, 2012). *Taxus globosa*, or Mexican yew is known in Spanish by the names of *tejo mexicano*, *palmira* and *tlascal* (Zavala, 2001, 2002); in northern Mexico it is called *chiper*, and in central and southern Mexico, *romerillo* or *granadillo* (Contreras and Luna, 2001; Soto *et al*., 2011).

Of the four native taxa of this genus in the Western hemisphere —the least known, until recent years— was the Mexican species *Taxus globosa*, which is sporadically distributed from the central part of the Northeastern region (*Nuevo León* and *Tamaupipas*), the Gulf of Mexico basin and the Transversal Neovolcanic Axis to the south of Honduras (Zamudio, 1992; Zavala, 2001, 2002; Spjut, 2007b). According to Spjut (2007a; 2007b), there are two varieties: *T. globosa* var. *globosa* Schlecht. and *T. globosa* var. *floridana* (Nutt. ex. Champ.) Spjut; the difference between them lies in the shape of the papillae on the leaves: in the *globosa* variety, distributed between El Salvador and Northeastern Mexico, the papillae are prominent in most of the surface of the underside, and the marginal cells are mostly sinuous, whereas in the *floridana* variety, which occurs only in the states of *Nuevo León, Tamaulipas* and *Veracruz,* the papillae are less prominent in the central nervation and in the marginal area, and the marginal cells are more or less rectangular in shape.

The species of the *Taxus* genus are conifers that are susceptible of forest exploitation (poles, firewood and charcoal), in addition to their pharmaceutical use, since they produce the drug known as *taxol*, which is important in the treatment of ovarian and breast cancer (Wani *et al.*, 1971) and is promising for the treatment of other types of malign tumors (Arbuck and Blaylock, 1995). Chemically, *taxol* is a diterpene pseudoalkaloid, isolated little over 20 years ago from the bark of the yew of the Pacific

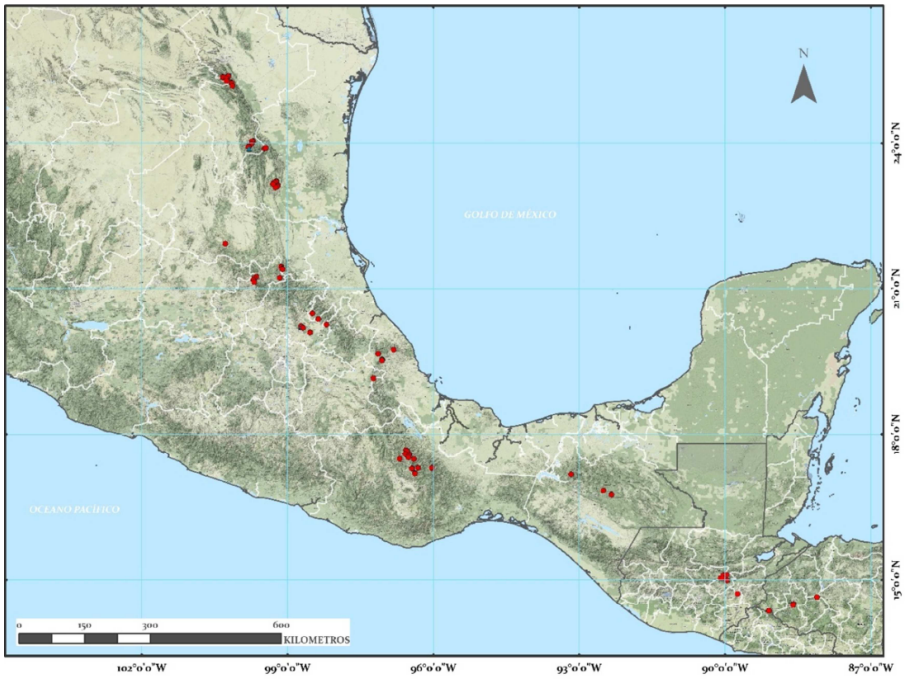
or from the American yew (*Taxus brevifolia* Nutt), which is thin (approximately 3 mm). In average, a tree aged one-hundred years produces 3 kg of bark, which yield only 300 mg of *taxol* (Appendino *et al.*, 1994). On the other hand, in the Mexican species, the levels of *taxol* vary between 0.013 % in 20 g of foliage and 0.0085 % in 20 g of bark (Soto *et al.*, 2000). The fact that the largest proportion of the active principle is found in the leaves confers it particular interest, as its exploitation is based on the foliage, for debarking causes the death of the tree.

For this reason, the objective of the present work is to show the status of the knowledge of the natural and potential distribution of the species in Mexico, the vegetal associations, the conservation status, and the aspects of the reproduction of *Taxus globosa*, in order to orient the future research on these topics to promote conservation actions and sustainable techniques for the exploitation of the species.

Current and potential distribution

Taxus globosa is a native species of Mexico and of northern Central America (Zamudio, 1992; Spjut, 2007). Its distribution area covers from 25°23' N in the state of *Nuevo León*, Mexico, to 14°19' N in the department of *Chalatenango, in El Salvador* (Contreras-Medina *et al*., 2011) (Shemluck *et al*., 2003). In Mexico, its distribution is sporadic along the Eastern *Sierra Madre* in *Nuevo León, Tamaulipas, Querétaro, Hidalgo, Puebla* and *Veracruz* (Contreras and Luna, 2001); *San Luis Potosí* (García and Castillo, 2000); in *Sierra Juárez*, *Oaxaca* (Zamudio, 1992), and in the Highlands of *Chiapas* (Contreras and Luna, 2001).

It is also found in the temperate forests of *Guatemala*, located in the *Sierra de las Minas* Biosphere Reserve, in the *Sierra of Cuchumatanes*, and in the Volcanic Chain (Standley and Steyermark, 1958; Parker, 2008); in Southern *El Salvador*, on the top of the *Pital* mountain (Moldenke and Moldenke, 1984), and in Western *Honduras*, in the *Santa Bárbara, Celaque* and *Tilarán* national parks, the last of which is considered as the southernmost boundary of its distribution area (Zamudio, 1992; Contreras-Medina *et al*., 2010,2011; López and García, 2015) (Figure 1).



Taken from López and García (2015).

Figure 1. Geographic distribution of *Taxus globosa* Schltdl.

Taxus globosa requires very particular microclimate conditions for its establishment, including specific levels of light, water, temperature and humidity determined by the microtopography of the site (García and Castillo, 2000; Contreras and Luna, 2001). In this regard, Sánchez (2012) determined that in two localities of *Veracruz*, the populations of *Taxus* were at sites with average temperatures of 14.5 and 15.4 °C, with relative humidity above 80 % and with levels of light of 2.5 to 3.2 mmol m^{-2} s^{-1}; furthermore, García and Castillo recorded their presence in ravines with north-northeast exposures.

In particular, Mexican populations are geographically restricted and do not form large stands (López and García, 2015); seemingly, their distribution is partly influenced by historical factors of how conifers were introduced to Mexico and Central America by the northern part of the hemisphere in the second half of the Tertiary period (Mirov, 1967; Hils, 1993), and therefore, for Rzedowski (2006) it is one of the species with a discontinuous distribution that establish a floristic relationship with the east of North America (the United States of America and Canada) and it is part of the deciduous

forest in the United States of America (*Taxus brevifolia* Nutt.) and of the montane cloud forest of Mexico and Central America (*Taxus globosa*) (Zavala, 2001) in the process of its migration toward the south, as has been suggested for other taxa and vegetal associations (Pearson and Dawson, 2003).

There are studies that have expanded the knowledge of the geographic distribution and the potential of the species, through the estimation of the ecological niche based on the use of algorithms such as Maxent and Bioclim (Contreras-Medina *et al.*, 2010, 2011; García-Aranda *et al*., 2012a, 2012b; López and García, 2015). On this particular, Contreras-Medina *et al.* (2010) generated potential distribution maps using three distribution scenarios per change in land use, at different times and with Maxent-generated models of the remaining potential distribution of the species in federal natural protected areas (NPA) and Prioritary Terrestrial Regions (PTR) for conservation. In relation to this work, Contreras-Medina *et al.* (2011) indicate that the species has been registered in only seven NPAs of all Mesoamerica, four of which belong to Mexico, with a 19.67 % cover (Table 1). In addition, six points of occurrence of *T. globosa* were located at less than 5 km of distance from the boundaries of a NPA, although reportedly the species hardly occurs in two of them due to the tropical and dry climate prevalent in both: Valley of *Tehuacán-Cuicatlán* and the *Metztitlán* Ravine (Table 2). López and García (2015) located 75 towns distributed in nine states (Table 3).

Table 1. Natural Protected Areas in Mexico where *Taxus globosa* Schltdl. has been registered.

Natural Protected Area	Num. of registers	Occupied % of the NPA
Monterrey Peaks National Park	3	0.16
"La Tierra del Faisán" Communally Managed Land	1	1.03
El Chico National Park	7	18.25
Sierra Gorda Biosphere Reserve	9	0.23
Total	20	19.67

Modified by Contreras-Medina *et al*. (2011).

Table 2. Natural Protected Areas in Mexico near whose boundaries *Taxus globosa* Schltdl. has been registered (within 5 km).

Natural Protected Area	Distance (km)
Mexican Wolf Ecological Recovery Area, *El Saucillo*, *Nuevo León*	3.74
Metztitlán Gully Biosphere Reserve, *Hidalgo*	4.88
Cofre de Perote National Park, *Veracruz*	1.88
Peak of *Orizaba* National Park, *Veracruz-Puebla*	2.14
Tehuacán-Cuicatlán Biosphere Reserve, *Oaxaca-Puebla*	0.77
Communal Conservation Area, *Santo Domingo Cacalotepec*, *Oaxaca*	2.08

Modified by Contreras-Medina *et al*. (2011).

Table 3. *Taxus globosa* Schltdl. populations located in Mexico.

State	Num. of populations	Latitude (Extreme Lower)	Longitude (Extreme Lower)	Altitude (m)
Nuevo León	16	25°22′35″ 23°53′25″	100°13′15″ 99°47′29″	1 460 2 650
Tamaulipas	12	23°55′20″ 23°02′48″	99°28′18″ 99°14′50″	1 300 1 400
San Luis Potosí	1	21°55′40″	100°16′40″	2 000
Querétaro	8	21°27′26″ 21°08′14″	99°07′48″ 99°41′06″	1 980 2 620
Hidalgo	9	20°22′01″ 20°05′23″	98°20′22″ 98°32′04″	2 260 2 630
Puebla	1	20°15′00″	98°12′00″	2 000
Veracruz	9	20°36′00″ 19°09′00″	98°26′20″ 97°14′00″	1 720 2 500
Oaxaca	16	17°40′29″ 17°11′00″	96°33′54″ 96°24′00″	2 400 2 500
Chiapas	3	17°10′00″ 16°50′00″	93°10′00″ 92°30′00″	1 750 2 300

Modified by López and García (2015).

The potential distribution of *T. globosa* in Mexico suggests the existence of 35 259 km^2, without considering the impact caused by the change of land use (Contreras-Medina *et al*., 2010). García-Aranda *et al*. (2012b) determined that the species has a very limited potential distribution area, of 9 650 km^2 (*Bioclim*) to 10 385 km^2 (*Bioclim*+Topography being the most significant model), which amount to 0.49–0.52 % of the national territory.

The potential distribution models show a major reduction of the area due to the change of land use (Contreras-Medina *et al*., 2010); furthermore, the variables slope and precipitation of the driest month are the ones that exert the greatest influence (García-Aranda *et al*., 2012a). According to Contreras-Medina *et al*. (2010), in 1976 *T. globosa* covered a surface area of 26 620 km^2 (a 24.5 % reduction of the original vegetation without human intervention; for the year 1996 they estimated 6 847 km^2 (*i.e*. an 80.58 % reduction, and for the year 2000 they estimated 6 297 km^2 (an 82.14 % reduction).

For the year 2000, Contreras-Medina *et al.* (2010) estimated the potential distribution area of the species within the NPAs in 744 km^2, which amounted to 11.8 % of the potential surface area distributed through 10 NPAs along the Eastern *Sierra Madre* and the *Sierra Madre* of *Oaxaca* (the *Monterrey* Peaks, *Sierra Gorda* of *Guanajuato*, *Sierra Gorda, Los Mármoles,* the *Metztitlán* Gully, the *Necaxa* River Hydrographic Basin, *Cofre de Perote, Orizaba* Peak, the White River Canyon (*Cañón de Río Blanco*), and the Valley of *Tehuacán-Cuicatlán*). Notably, the potential surface area located in *Chiapas* does not coincide with any federal NPA. The potential surface area of *T. globosa* located in one of the Priority Terrestrial Regions (PTR) was 3 052 km^2, the equivalent of 48.46 % of the potential area for the year 2000, and it coincides with 15 PTR along its distribution area (Contreras-Medina *et al*., 2010).

A potential habitat with less probabilities of occurring, but which meets the environmental requirements of the species, has also been identified in the states of *Querétaro, Oaxaca, Guanajuato, Chiapas, San Luis Potosí, Coahuila*, State of Mexico, *Tlaxcala, Morelos, Jalisco* and *Colima* (Contreras-Medina *et al*., 2011). The presence

of *T. globosa* in the State of Mexico was recorded by Standley (1926) and, although there are no herbarium specimens to support this information, the model of the ecological niche predicts its existence in this state (Contreras-Medina *et al*., 2010).

Vegetal associations and dendrometry

Taxus globosa grows in the middle and lower canopy, beneath the shade of other, taller trees, in environments with a high relative humidity, near intermittent or permanent water runoffs (Soto *et al.*, 2011); in north-northeast exposures (García and Castillo, 2000; García-Aranda *et al*., 2012a), with varied slopes; for example, on the *San Isidro* plateaus, in *Río Verde, San Luis Potosí* (García and Castillo, 2000), the slope is 40 %, and at the *El Chico* National Park in *Hidalgo*, it ranges between 10 and 60 % (Zavala, 2001). The species exhibits a strong preference for growing at the bottom of humid, shaded ravines, due to rain precipitations or to frequent mists; it grows on acidic soils with a good drainage and rich in organic matter (Cortés *et al.*, 2000; Charco, 2007).

In pine-oak forests, the species coexists with *Pinus pseudostrobus* Lindl.*, P. ayacahuite* Ehrenb.*, P. patula* Schltdl. *et* Cham.*, Arbutus xalapensis* Kunth*, Quercus crassifolia* Bonpl.*, Q. germana* Schltdl. *et* Cham.*, Q. rysophylla* Weath.*, Q. laurina* Bonpl.*, Tilia mexicana* Schlecht.*, Meliosma dentata* Urban.*, Abies religiosa (*Kunth) Schltdl. *et* Cham., and *A. vejarii* subsp. *mexicana* (Martínez) Farjon (García and Castillo, 2000; López and García, 2015); in the montane cloud forest, it is associated with *Ostrya virginiana* (Mill.) K. Koch*, Liquidambar styraciflua* L.*, Cornus disciflora* DC. (Luna *et al*., 1994), *Fraxinus* sp., *Magnolia tamaulipana* A. Vázquez, *Ternstroemia sylvatica* Schltdl. *et* Cham. (García-Aranda *et al*., 2012a), *Persea americana* Mill., and *Quercus affinis* Scheidw (García and Castillo, 2000) (Table 4).

Table 4. Distribution of *Taxus globosa* Schltdl. and associated genera.

State	Altitude (m)	Associated genera
Hidalgo	2 500-2 600	*Abies, Quercus*
Querétaro	1 000-2 900	*Abies, Garrya, Pinus*
Nuevo León	2 600-2 700	*Pinus, Pseudotsuga, Abies, Quercus*
Oaxaca	2 000-3 000	*Pinus, Quercus*
San Luis Potosí	2 300-2 500	*Pinus, Garrya*
Tamaulipas	1 400-1 500	*Quercus, Liquidambar, Podocarpus, Acer*
Veracruz	1 900-2 500	*Cupressus, Pinus, Quercus*

Modified by Zavala (2001).

Few studies document the structure, composition, richness and diversity of the vegetation of the *T. globosa* stands, which in general are described as mere field observations, and, therefore, the age structure, growth, development, and regeneration mechanisms of the Mexican populations are unknown. The populations of the Southernmost sector of the Northeastern region of Mexico have a larger basal area, a greater height and a smaller herbaceous cover than the northern populations, which are located at more disturbed sites, and, likewise, the southern sites are located at higher altitudes, with a greater slope than that prevalent in the north. Thus, their structure is influenced by the environmental heterogeneity, the characteristics of the localities, and the degree of disturbance of the populations (García-Aranda *et al*., 2012a).

T. globosa stands usually have a limited density of individuals and surface area; its dasometric characteristics are very variable between populations (Table 5). In more isolated areas, far from human settlements and with lower degree of direct (furtive felling) or indirect (bovine and goat cattle management) anthropic impact, there is a higher density of individuals. Those areas that are fenced and protected from the cattle are not very densely populated but exhibit a higher ratio of juvenile to adult individuals (Zavala *et al*., 2001). On the other hand, areas with a steep relief,

pronounced slopes and high stoniness have a great density of seedlings, indicating stability and durability of the population, as suggested by Iszculo *et al.* (2005), for the European yew.

Table 5. Mensuration variables in *Taxus globosa* Schltdl. populations of central Mexico.

State	Locality	Density (individuals ha^{-1})	Medium height (m)	Maximum height (m)	Basimetric area (m^2 ha^{-1})	Source
	El Mirador	670	2.8	7.0	8.40	
Veracruz	*El Saucal*	310	1.1	1.9	0.24	Sánchez, 2012
	Las minas	500	0.5	1.2	2.01	
Nuevo León		5 a 39	2.0	6.8	23.03	García-Aranda *et al.*, 2011
Tamaulipas		0.9	2.0	6.8	82.32	
Hidalgo	*El Chico*	6.6	4.5	-	-	Zavala, 2002
San Luis Potosí	*Río Verde*	-	-	8.0	-	García and Castillo, 2000

Conservation status and reproduction

The species is rare in many of the localities where its occurrence has been recorded (Contreras *et al*., 2001). Since little is known of the distribution, density, structure, composition and wealth of its populations, it has been classified as Subject to Special Protection (Pr) by the Mexican Official Norm NOM-059-SEMARNAT-2010 (Semarnat, 2010), which means that it may be threatened by factors that exert a negative influence on its viability; therefore, it has been determined that there is a need to favor its recovery and conservation, or the recovery and conservation of the populations of the species associated to it. At the international level, *T. globosa* is included in the red list of threatened species of the International Union for Conservation of Nature (IUCN) as an endangered species because its area of occupancy is less than 2 000 km^2, probably due to past and current exploitation, as well as to the deforestation of the montane cloud forest and of other ecosystems where it grows; these factors led to the reduction of the population size, which may continue (González-Espinosa *et al*., 2011; Thomas, 2013).

According to López and García (2015), out of 29 assessed *T. globosa* populations, 15 had a good conservation status, based on their acceptable natural regeneration; two had an inadequate conservation status, due to the low density of specimens, and 12 exhibited totally unfavorable conditions and were at risk of disappearing, due to the change of land use, deforestation, and the fragmentation of their habitat.

The isolation between the populations leads to assume the existence of a limited gene flow; besides, the exploitation of this and other *taxa* of the upper tree canopy involves a high risk for the conservation of the species (Soto *et al*., 2011). Therefore, it is necessary to know the biology and forms of reproduction of the natural populations in order to ensure their conservation. According to Zavala (2001), very precise, local information has been generated about their reproductive characteristics of the populations of *El Chico, Hidalgo*, and about the forms of propagation, the number of male and female specimens, the proportion between juvenile and adult trees, and the aspects of their natural regeneration (Zavala, 2002).

Zavala *et al*. (2001) observed that regeneration seems to be based on seed production, although at certain sites there is a significant production of new shoots from the stem base up (López, 2008) —a characteristic that may be exploited for its *ex situ* propagation and conservation. Nevertheless, the seeds are the most important structures for ensuring the permanence and genetic diversity of the populations; but, unfortunately, their production is limited, and their germination is very difficult (Ramírez-Sánchez *et al*., 2011).

Reproduction of *T. globosa* from seeds has been unsuccessful (Zavala-Chávez, 2001; Nicholson and Munn, 2003) due to underdevelopment of the embryo, which is indicative of morphological latency (Ramírez-Sánchez *et al.,* 2011). According to Ramírez-Sánchez (2018), their latency has various causes (including physiological ones) which render germination even more difficult; for this reason, only vegetative methods have brought success (Muñoz *et al.*, 2009).

Ramírez-Sánchez *et al*. (2011) determined that the morphological variables and the physical characteristics of the *T. globosa* seeds exhibit significant differences between

geographical regions, as the seeds of northern Mexico are larger than those of central Mexico; such differences were ascribed to the fragmentation of the habitat, to the small size of the populations and to the genetic drift, as the populations of central Mexico consist of 10 to 200 individuals, while in the northern region, they are estimated to comprise 1 000 to 5 000 individuals.

A low production of seeds has also been observed, which suggests that the species follows an inter-annual regeneration pattern (López and García, 2015); for this purpose, the population is required to include a minimum number of adults, with an adequate proportion between the sexes, in order to achieve an effective pollination and minimum rates of seed formation. At the *El Chico* National Park, out of 251 individuals, 29.9 % were adults; of these, 44.0 % were female, and 56 % were male (Zavala, 2002). However, Soto *et al.* (2011) determined that the male/female ratio is close to 50:50 in all the populations. Only 6 to 15 seeds per ripe tree are produced, as a result of the proportion between mature and juvenile trees. For example, of 150 individuals observed, only 32 % female specimens were reproductively mature, while more than half (68 %) were juvenile, with a mean estimated age of 10.6 years (± 8.0), the oldest trees being 19 years old, and the youngest, 3 years (Zavala *et al*., 2001).

Apparently, few juvenile trees have been incorporated into the population in the last few years, which may indicate reduction of the population or of the seed production; but, the number of individuals that make up the whole population is unknown, as are their ages, their annual seed production, the number of seeds that eventually germinate, and the survival rate of the seedlings (Zavala *et al.*, 2001).

Conclusions

Given the exploitation potential of *Taxus globosa* for pharmaceutical purposes, the following actions are required: a) to develop programs for the recovery and conservation of the natural populations of the species, and b) in the case of certain natural protected areas, field work must be carried out to verify its occurrence and propose its inclusion in the NPA management and conservation programs. Likewise, it is necessary to complement the studies on: a) its current and potential distribution in Mexico, as there is no inventory of the distribution of the remaining natural populations; b) the structure of its population, including size, number of individuals, male/female ratio, management status and degree of disturbance of the populations; c) demographic and ecological studies must be carried out, and knowledge of the complete reproductive cycle of the species needs to be generated; d) its breeding system must be identified in order to promote the production of seeds in programs for the domestication of the species; e) the seed dispersing fauna must be identified; f) vegetative propagation methods must be developed in order to undertake *ex situ* conservation actions in botanical gardens and in forest germplasm production units.

There is equally a need to expand the knowledge regarding the relationship to the physiology of the species as a way of establishing conservation and management actions aiming to promote its permanence *in situ* and its propagation *ex situ*, as well as to identify those factors that affect the natural populations, such as climate change or the degree of modification of the habitat due to changes in land use.

There are no programs for the protection, artificial repopulation or protection of this conifer. It is desirable to continue multiplying it by stake rooting —especially of those individuals that are outstanding for their high taxol contents—, in order to assess the genetic control of this characteristic and explore the possibility of domesticating the species through the establishment of commercial plantations for the exploitation of this active principle, as well as to generate information about the genetic diversity within and between populations.

Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Liliana Muñoz-Gutiérrez: literature review, drafting and editing of the manuscript; Susana E. Ramírez-Sánchez: contribution of bibliographic materials and editing of the manuscript; Mario Valerio Velasco-García drafting and editing of the manuscript.

References

Appendino, G., G. Cracotto, P. L. Gariboldi, B. Gabetta and E. Bombardelli. 1994. The chemistry and occurrence of taxane derivatives. The Photochemistry of Taxine B. Gazzetta Chimica Italiana 124:1-4.

Arbuck S., G. and B. A. Blaylock. 1995. Taxol: Clinical results and current issues in development. *In*: Suffness, M. (ed.). Taxol: Science and Applications. CRC Press. Boca Raton, Florida. USA. pp. 379-415.

Barrales-Cureño, H. J. y M. Soto-Hernández. 2012. Taxoides: metabolitos secundarios del árbol del tejo (*Taxus* spp.). Revista Chapingo Serie Ciencias Forestales y del Ambiente 18(2):207-218. Doi: 10.5154/r.rchscfa.2011.02.017.

Charco, J. 2007. El tejo en el norte de África. *In*: Serra, L. (ed.). El tejo en el Mediterráneo Occidental. Conselleria de Territori i Habitatge. Ministerio de Medio Ambiente. CAM. Madrilas, Ciudad Real, España. pp. 177-185.

Contreras M., R. y I. Luna V. 2001. Presencia de *Taxus globosa* Schltdl. (Taxaceae) en el estado de Chiapas, México. Polibotánica 12:51-56.

Contreras-Medina, R., I. Luna-Vega y C. A. Ríos-Munoz. 2010. Distribución de *Taxus globosa* (Taxaceae) en México: Modelos ecológicos de nicho, efectos del cambio de uso de suelo y conservación. Revista Chilena de Historia Natural 83:421-433.

Contreras-Medina, R., I. Luna-Vega y J. C. Ramírez-Martínez. 2011. Representatividad del tejo mexicano (*Taxus globosa* Schltdl., Taxaceae) en las áreas naturales protegidas de Mesoamérica. Spanish Journal of Rural Development 2(2):51-60. Doi: 10.5261/2011.ESP2.06.

Cope, E. A. 1998. Taxaceae: The genera and cultivated species. The Botanical Review 64(4):291-322.

Cortés S., F. Vasco y E. Blanco. 2000. El libro del Tejo (*Taxus baccata* L.). Un proyecto para su conservación. ARBA.A. Madrid, España. 336 p.

García-Aranda, M. A., A. E. Estrada-Castillón, E. Jurado-Ybarra y D. U. González-Uribe. 2011. Análisis de once poblaciones naturales de *Taxus globosa* en la Sierra Madre Oriental. Madera y Bosques 17(1):93-104. Doi: 10.21829/myb.2011.1711156.

García-Aranda, M. A., A. E. Estrada-Castillón, C. M. Cantú-Ayala y M. Pando-Moreno. 2012a. Clasificación de nueve sitios de bosque mixto de coníferas con presencia de *Taxus globosa* en la Sierra Madre Oriental, Nuevo León y Tamaulipas, México. Botanical Sciences 90(1):53-62. Doi: 10.17129/botsci.385.

García-Aranda, M. A., C. Cantú-Ayala, E. Estrada-Castillón, M. Pando-Moreno y A. Moreno-Talamantes. 2012b. Distribución actual y potencial de *Taxus globosa* (Taxaceae) en México. Journal of the Botanical Research Institute of Texas 6(2):587-598.

García S., F. y P. Castillo L. 2000. Aspectos ecológicos de *Taxus globosa* Schlecht. en las Mesas de San Isidro, municipio de Río Verde, San Luis Potosí. Biotam 11(3):11-18.

González-Espinosa, M., J. Meave, F. G. Lorea-Hernández, G. Ibarra-Manriquez and A. C. Newton. 2011. The red list of Mexican cloud forest trees. Fauna & Flora International. Cambridge, UK. 153 p.

Hansen R., C., K. D. Cochran, H. M. Keener and E. M. Croom. 1994. *Taxus* populations and clippings yields at commercial nurseries. HortTechnology 4(4):372-377.

Hils, M. H. 1993. Taxaceae Gray: yew family. *In:* Flora of North America Editorial Committee (eds.). Flora of North America north of Mexico, Vol. 2. Pteridophytes and gymnosperms. Oxford University Press. New York, NY, USA. pp. 423–427.

Iszcuło, G., A. Boratyńsky, Y. Didukh, K. Romaschenko and N. Pryazhko. 2005. Changes of population structure of *Taxus baccata* I. during 25 years in protected area (Carpathians, Western Ukraine). Polish Journal of Ecology 53(1):13-23.

López U., J. and X. García M. 2015. *Taxus globosa* Schltdl. (Taxaceae). Distribution and diagnosis of an endangered yew. Earth Sciences 4(3-1):80-88. Doi: 10.11648/j.earth.s.2015040301.13.

López, H. M. 2008. *Taxus globosa* Schltdl., una especie medicinal en el Parque Nacional El Chico, Hidalgo. *In*: Pulido F., G., A. L. López E. y M. T. Pulido S. (eds.). Estudios biológicos en las áreas naturales del Estado de Hidalgo. Universidad Autónoma del Estado de Hidalgo. Pachuca, Hgo., México. pp. 63-68.

Luna V., I., S. Ocegueda C. y O. Alcántara A. 1994. Florística y notas biogeográficas del bosque mesófilo de montaña del Municipio de Tlanchinol. Hidalgo. México. Anales del Instituto de Biología. Serie Botánica 65(1):31-62.

Mirov, N. T. 1967. The genus *pinus*. The Royal Press. New York, NY, USA. 602 p.

Moldenke, H. N. and A. I. Moldenke. 1984. An International census of the coniferae. *In*: Silba, J. (comp.). Phytologia Memoirs VII. Plainfield, NJ, USA. 79 p.

Muñoz G., L., J. J. Vargas H., J. López U. and M. Soto H. 2009. Effect of cutting age and substrate temperature on rooting of *Taxus globosa*. New Forests 38:187-196. Doi: 10.1007/s11056-009-9139-6.

Nicholson, R. and D. X. Munn. 2003. Observations on the propagation of *Taxus globosa* Schltdl. Boletín de la Sociedad Botánica de México 72:129-130. Doi: 10.17129/botsci.1673.

Parker, T. 2008. Trees of Guatemala. The tree press, Austin, TX, USA. 1033 p.

Pearson, R. G. and T. P. Dawson. 2003. Predicting the impacts of climate change on the distribution of species: Are bioclimate envelope models useful? Global Ecology & Biogeography 12:361-371. Doi: 10.1046/j.1466-822X.2003.00042.x.

Ramírez-Sánchez, S. E., J. López-Upton, G. García de los S., J. J. Vargas-Hernández, A. Hernández-Livera y O. J. Ayala-Garay. 2011. Variación morfológica de semillas de *Taxus globosa* Schltdl. provenientes de dos regiones geográficas de México. Revista Fitotecnia Mexicana 34:93-99.

Ramírez-Sánchez, S. E., J. López-Upton, J. J. Vargas-Hernández, O. J. Ayala-Garay, G. García de los S. and M. R. Soto-Hernández. 2018. Pregermination treatments of *Taxus globosa* seeds: Growth and *in vitro* embryo culture. Journal of Tropical Forest Science 30(4):528-536. Doi: 10.26525/jtfs2018.30.4.528536.

Rzedowski, J. 2006. Vegetación de México. 1ª Edición digital. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México, D.F., México. 504 p.

Sánchez P., L. A. 2012. Caracterización del hábitat de *Taxus globosa* Schltdl. (Taxaceae) en la Cuenca del Alto Pixquiac, Veracruz. Tesis de Maestría. Instituto de Ecología A.C. Xalapa, Ver., México. 55 p.

Secretaría de Medio Ambiente y Recursos Naturales (Semarnat). 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, 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. México, D.F., México. 77 p.

Shemluck, M. J., E. Estrada, R. Nicholson and S. W. Brobst. 2003. A preliminary study of the taxane chemistry and natural history of the Mexican yew, *Taxus globosa* Schltdl. Boletín de la Sociedad Botánica de México 72:119-127. Doi: 10.17129/botsci.1672.

Soto H., M., J. López U., J. J. Vargas H., L. Muñoz G. y R. San Miguel. 2011. Estado de conservación de *Taxus globosa* en México. Spanish Journal of Rural Development 2:61-68. Doi: 10.5261/2011.ESP2.07.

Soto H., M., M. Sanjurjo, M. T. González G., D. Cruz V. y F. Giral G. 2000. El tejo mexicano (*Taxus globosa* Sch.). Potencial de su aprovechamiento en taxol. Ciencia Ergo Sum 7(3):277-279.

Spjut, R. W. 2007a. Taxonomy and nomenclature of *Taxus* (Taxaceae). Journal of the Botanical Research Institute of Texas 1:203-289.

Spjut, R. W. 2007b. A phytogeographical analysis of *Taxus* (Taxaceae) based on leaf anatomical characters. Journal of the Botanical Research Institute of Texas 291-332.

Standley, P. C. and J. A. Steyermark. 1958. Flora of Guatemala. Fieldiana Botany 24:60-63.

Standley, P. C. 1926. Taxaceae. *In*: Trees and shrubs of Mexico. Contributions from the United States National Herbarium 23:50-51.

Thomas, P. 2013. *Taxus globosa*. The IUCN Red List of Threatened Species 2013. http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T30724A2795235 (7 de septiembre de 2018).

Wani, M. C., H. L. Taylor and M. E. Wall. 1971. Plant antitumor agents VI. The isolation and structure of taxol, a novel antileukemic and antitumor agent from *Taxus brevifolia*. Journal of the American Chemical Society 93:2325-2327.

Zamudio R., S. 1992. Familia Taxaceae. *In*: Rzedowski, J. y G. Calderón (eds.). Flora del Bajío y de regiones adyacentes. Fascículo 9. Instituto de Ecología, Pátzcuaro, Michoacán, México. pp. 1-6.

Zavala C., F. 2001. Análisis demográfico preliminar de *Taxus globosa* Schlecht en el Parque Nacional El Chico, Hidalgo, México. I: Población de adultos y algunas características del hábitat. Ciencia Ergo Sum 8(2):169-174.

Zavala C., F. 2002. Análisis demográfico preliminar de *Taxus globosa* Schlecht en el Parque Nacional El Chico, Hidalgo, México. II. Población de juveniles y algunos datos de semillas. Ciencia Ergo Sum 9(2):177-183.

Zavala C., F., M. Soto H. y Ma. T. Rodríguez G. 2001. El romerillo (*Taxus globosa* Schlecht.): biología, dificultades y perspectivas de su uso. Revista Chapingo Serie Horticultura 7(1):77-94. Doi: 10.5154/r.rchsh.1999.02.016