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Article

Características estructurales y demográficas de *Juniperus deppeana* Steud. en dos localidades del estado de Tlaxcala

Structural and demographic characteristics of *Juniperus deppeana* Steud. in two locations in *Tlaxcala* State

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Resumen

Juniperus deppeana es una especie tolerante a la sequía y al fuego, capaz de desarrollarse en suelos con condiciones adversas, razón por la cual se le considera una especie con potencial para la conservación de suelos. Sin embargo, en México ha sido poco estudiada, ya que no tiene un valor relevante en la industria forestal. En el estado de Tlaxcala existen poblaciones abundantes de este género, por lo que se seleccionaron las localidades El Pardo (EP) y Acopinalco del Peñón (RAP) para analizar las características estructurales y demográficas de los individuos presentes de *J. deppeana*; así como determinar la influencia de algunos factores abióticos. Los análisis de *t* de *Student* indicaron valores promedio significativos en la altura, diámetro mayor, diámetro menor y en la cobertura. No se obtuvo relación significativa entre las variables dasométricas con la pendiente y la orientación de las parcelas de muestreo. La relación del DAP con la cobertura fue significativa. La curva de supervivencia para ambas localidades presentó un patrón tipo III. Los análisis estadísticos confirmaron que la estructura de tamaños difiere entre los sitios de muestreo. Se deduce que el comportamiento poblacional de *J. deppeana* acusa una pérdida alta de individuos jóvenes, lo que supone un riesgo para su regeneración natural. Por otro lado, aunque los ejemplares en el predio sujeto a manejo forestal reúnen características dasométricas más favorables, se requiere de estudios a largo plazo bajo un enfoque más integral, a fin de determinar las posibilidades de conservación de esta especie.

Palabras clave: Análisis de correlación linear angular, datos dasométricos, manejo forestal, Método de Desarrollo Silvícola, Método Tlaxco, tablas de vida estáticas.

Abstract

Juniperus deppeana is a drought and fire tolerant species, able to grow under adverse soil conditions, and is therefore considered a potentially useful species for soil conservation. However, in Mexico, studies in this species are scarce, since it is not economically relevant for the forest industry. In *Tlaxcala* State there are abundant populations of this genus, so two localities, *El Pardo* (EP) and *Acopinalco del Peñón* (RAP), were chosen to analyze the structural and demographic characteristics of *J. deppeana* individuals, as well as to determine the influence of some abiotic factors. The Student's t-tests indicated significant mean values in height, maximum diameter, minimum diameter and crown cover. No significant relationship was found between the mensuration variables and the orientation or slope of the plots. The relationship between DBH and the crown cover was significant. The survival curve for both localities had a type III pattern. Statistical analysis indicates that size structure differs between sampling sites. Furthermore, the behavior of *J. deppeana* populations shows a high loss of young individuals, which threatens its natural regeneration. Although individuals from the site with forest management have more favorable dasometric characteristics, further long-term studies are required, under a more comprehensive approach, to determine the prospects for the conservation of this species.

Key words: Angular-linear correlation analysis, mensuration data, forest management, Silvicultural Development Method, *Tlaxco* Method, static life tables.

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Introduction

Juniperus is the second most diverse conifer genus in the world after *Pinus* that include 67 taxa, 28 varieties and seven forms (Farjon, 2005). In Mexico, 16 species are known, of which *Juniperus deppeana* Steud. and *Juniperus flaccida* Schldtl. are the most widely distributed (Farjon, 2005).

The genus *Juniperus* has two centers of origin: southeastern United States of America, where it grows profusely; and northeastern Mexico, where a large number of species grow, both in semi-desertic and mountainous areas (Martínez, 1963; Rzedowski, 1988; Adams, 2004). Additionally, the taxa inhabits high latitudes of the Northern Hemisphere and the Eurasian continent, in climates that range from temperate to cold (Farjon, 2005). In Mexico, individuals of the genus colonize very degraded places and form part of the secondary vegetation; they are of early appearance, and permanence is associated to disturbances originated by human activities (Ern, 1973; Rzedowski, 1988).

Juniper wood is used to make furniture and handicrafts (Gutiérrez, 1981), and because of its resistance to rot (German, 2006), it is used to manufacture windows and poles (Batis *et al.*, 1999). It also has medicinal, ornamental and religious uses (Troseau and Pidoux, 1842; Martínez, 1969; Barger and Ffolliott, 1972; Conafor, 2007).

In Mexico, juniper populations occupy approximately 0.15 % of the national territory and are distributed from *Baja California* and *Tamaulipas* to *Chiapas* (Adams, 2004); they are found in the transition zones between the *Quercus*, *Pinus* and *Abies* forests, as well as in grasslands and in xerophytic scrubland (Vázquez *et al.*, 2002).

Rzedowski (1988) points out that *J. deppeana* Steud. is a taxon that forms forests in different parts of Mexico; for example in the Western *Sierra Madre* and the Transverse Volcanic Axis. They also form a belt that covers an extensive area between *Perote*, *Veracruz*, and *Apizaco* in *Tlaxcala* State. Here, *J. deppeana* is present in association with *Agave atrovirens* Karw. ex Salm-Dyck, *Quercus* spp., and *Arbutus glandulosa* M. Martens & Galeotti, and occasionally grows in grasslands (SAG, 1975).

Research into *J. deppeana* in Mexico is still scarce, and encompasses several studies regarding pests and diseases (González, 1980; Cibrián *et al.*, 1995; Trinidad, 1999; Martínez *et al.*, 2007), plant production (Trinidad, 1999; Salazar, 2001), and only one site index study (forest management) (Rodríguez *et al.*, 2015). This oversight may be explained as a consequence of a general preference for researching commercially valuable timber species (Bray and Merino, 2004); notwithstanding, this taxon exhibits attractive features that may be useful in restoration and reforestation programs for soil conservation and erosion control (Vázquez *et al.*, 2002; FAO-Conafor, 2012), such as drought and fire tolerance, as well as capacity to grow in compact, stony, poor or alkaline soils (Conafor, 2007). However, further study is required, in order to sustainably manage *Juniperus* populations and thereby contribute to conserving biodiversity, as well as the ecological, economic and social functions of these taxa in the areas where they are distributed (Aguirre-Calderón, 2015).

In this context, the following objectives were set: to determine whether there are differences in the structural and demographic characteristics of *J. deppeana* in two sites in *Tlaxcala* (*El Pardo* and *Acopinalco del Peñón*); and to evaluate the influence of the slope and orientation on various dasometric parameters.

Materials and Methods

Study area

El Pardo (EP) and *Rancho Acopinalco del Peñón* (RAP) are located in the northern part of the state of *Tlaxcala*, in the municipality of *Tlaxco*, which lies between 19°36' and 19°44' N and 97°57' and 98°23' W, at an altitude between 2 540 - 3 500 m, with a surface area of 575. 57 km^2. This municipality corresponds to 14.4 % of the state territory (INEGI, 2009); it has a C(W$_2$)(w) temperate sub-humid climate, with a rainfall regime between June and September. Average rainfall is between 600 to 900 mm, with a maximum of 122.5 mm and a minimum of 7.6 mm (Inafed, 2010); the average temperature is between 10 to 14 °C (INEGI, 2009). The dominant soils are Phaeozem (66 %), Andosol (28 %), Vertisol (2 %), and Durisol (1 %) (INEGI, 2009).

At EP, the *Pinus* spp. forest is subjected to forest management (FM), through the *Tlaxco* Method, which includes logging and reforestation, with a rotation age of 54 years. The associated tree taxa include *Arbutus* sp., *Juniperus flaccida*, *Buddleja cordata* Kunth, *Quercus rugosa* Née, *Pinus rudis* Endl., and *Pinus teocote* Schiede. ex Schltdl. & Cham. In particular, *J. deppeana* is not considered a taxon of economic value due to its scarcity and to the hardness of its wood; however, as it develops near the source of the *Zahuapan* River, it functions as a soil protection species.

The RAP forest has been without forest management for over 10 years, although from 1992 to 2001 it was managed using the Silvicultural Development Method (MDS), which included the treatment of parent trees; in addition, in 1998 a fire affected the forest area. The tree and shrub taxa present include *Pinus rudis*, *P. patula* Schiede. ex Schltdl. *P. pseudostrobus* Lindl., *P. teocote*, *Agave* sp., and *Opuntia* sp., as well as *Phoradendron* sp. Cattle are grazed, and the wood of *J. deppeana* is used as firewood and occasionally to manufacture furniture.

For the analysis of EP, measurements of *J. deppeana* trees were performed in 16 plots of 33 × 33 m (1 089 m^2); whereas in RAP measurements were carried out in three plots with a similar surface area to those used at EP (Table 1). The central tree was marked with a Silva Polaris compass and with the aid of a 100 m Truper® measuring tape, 16.5 m were measured towards each cardinal point and marked with Sunglo Hi-Viz Ben Meadows phosphorescent flag tape (Zamora-Martinez *et al.*, 2007).

Table 1. UTM coordinates, altitude and slope of the selected sampling units at the study sites.

Site	Plot	UTM Coordinates		Altitude	Exposure	Slope
		X	Y	(m)		(%)
	1	594400	2169741	2 683	North	35
	2	594506	2169494	2 780	North	39
	3	594494	2169600	2 775	North	52
	4	594494	2169741	2 672	Northeast	30
	5	594600	2169400	2 780	North	30
	6	594600	2169494	2 731	Northeast	33
	7	594600	2169600	2 685	North	25
El Pardo	8	594600	2169741	2 680	North	25
	9	595000	2169200	2 760	Northeast	12
	10	595000	2169294	2 740	North	15
	11	595106	2169200	2 680	East	10
	12	595106	21699294	2 680	West	10
	13	595200	2169106	2 700	Norte	15
	14	595200	2169294	2 740	West	10
	15	595294	2169200	2 700	East	25
	16	595200	2169200	2 780	East	20
Rancho Acopinalco del Peñón	17	589210	2172730	2 751	Southeast	5
	18	589079	2172959	2 757	Southeast	20
	19	589064	2172844	2 741	Southeast	15.5

Dasometric evaluation

All standing trees with a normal diameter (ND) > 7.5 cm were included, and their total height (m) was measured with a HAGA® altimeter; the DBH (cm) was measured using a 16 mm wide Ben Meadows® 20 m/320 cm diameter tape; and the crown cover (CC) (m^2) was measured using a 15 m Truper® measuring tape and determined based on the average of the largest and smallest diameters (average crown diameter (ACD)), and then by calculating the radius and replacing it in the formula $CC = \pi\left(\frac{ACD}{2}\right)^2$ (Ugalde, 1981). Additionally, the basal area (cm^2), average density, percentage of basal area and crown coverage per plot were calculated. A t-Student test was performed, for which size of the sample from EP was randomly matched (n= 135) with that from RAP, using the Excel software, version 2010, to determine whether there are significant differences between the mean values of the study variables and between individuals from both sites (Zar, 2010).

Static life tables and size structure

Static life tables were compiled to determine certain population demographic parameters, and survival curves (Carabias *et al.*, 2009) were constructed from WTP intervals (Gurevitch *et al.*, 2006).

A X^2 analysis was applied to the size structures of the *J. deppeana* populations in the plots of interest in order to evaluate the frequency distributions among the plots. The expected data were calculated with a contingency table (Siegel and Castellan, 2009):

$$e_{ij} = \frac{R_i C_j}{N}$$

Where:

e_{ij} = Expected datum of row *i* and column *j*

R_i = Sum of the frequencies of row *i*

C_j = Sum of the frequencies of column *j*

N = Total observations

A standardized residual test of the contingency table was performed in order to determine whether the observed frequencies were significantly higher or lower than expected (Siegel and Castellan, 2009):

$$R = \frac{o - e}{\sqrt{e}} \sqrt{\frac{N - C_j}{N - R_i}}$$

It should be noted that the size categories used in the life tables were modified for a better management of the information, since no individuals were found past the 22.91–30.6 cm diametric interval.

Relationship between dasometric parameters and the plot slope and orientation

In order to determine the relationship between density, height, coverage and DBH, and the slope and orientation of the plots, a linear angular correlation analysis was performed, which allows the analysis of the angular data with a linear variable (Zar, 2010). The orientation data were converted to radians: N = 90º; NE = 45º; NW = 135º; W = 180º; S= 270º; SE = 315º; SW = 225º, and E = 360º. The general formula was:

$$r_{al} = \sqrt{\frac{r^2XC + r^2XS - 2rXCrXSrCS}{1 - r^2CS}}$$

Where:

r_{al} = Angular-linear correlation coefficient

r_{XC} = Correlation between the linear variable and the cosine of the angular variable

r_{XS} = Correlation between the linear variable and the sine of the angular variable

r_{CS} = Correlation between the cosine and the sine of the angular variable

The significance of the correlation coefficient was assessed by comparing r^2_{al} with $X^2_{g.l=2}$ (Zar, 2010).

A correlation was calculated between the density, and the dasometric variables height, DBH and crown cover, using the statistical package STATISTICA ver. 8 and Excel ver. 2010.

Results

Dasometric evaluation

The total basal area of all measured plots was larger at RAP than at EP; total coverage was relatively lower at RAP (Table 2). Most of the average values of the measured parameters (height, DBH, basal area, % basal area per plot, crown cover, % crown cover per plot) were higher at EP; although, in general, a low presence of junipers was observed in both plots (Table 3).

Table 2. Dasometric data of the *El Pardo* and *Rancho Acopinalco del Peñón* sites, in the municipality of *Tlaxco*, *Tlaxcala*.

Parameter	***El Pardo***	***Rancho Acopinalco del Peñón***
Number of registered plots	16	3
Number of registered trees	250	135
Basal area of the stems in the total area	3.07 m^2 ha^{-1}	6.91 m^2 ha^{-1}
Crown cover in the total area	1 700 m^2 ha^{-1}	1 600 m^2 ha^{-1}

Table 3. Mean values (± s.e.) of the dasometric parameters of the trees at the studied sites.

Dasometric parameter	**Site**	
	El Pardo	***Rancho Acopinalco del Peñón***
Height (m)	6.05 (± 0.10)	4.96 (± 0.11)
DBH (cm)	14.45 (± 0.10)	13.25 (± 0.11)
Basal area (cm^2)	213.98 (± 22.29)	167.11 (±17.77)
Percentage of basal area per plot	0.0020 (±0.0002)	0.0015 (±0.0002)
Crown cover (m^2)	12.15 (± 0.82)	3.76 (± 0.26)
Percentage of crown cover per plot	1.12 (± 0.08)	0.35 (± 0.009)

The *t*-Student analyses of the 135 randomly selected individuals revealed that EP exhibited significantly higher average values for height and crown coverage than RAP. However, no significant differences were found in the DBH or the mean basal area of individuals at each site (tables 4 and 5).

Table 4. Mean values (± s.e.) used in the statistical analyses of each sampled site.

Site	Height (m)	DBH (cm)	Basal area			Crown cover		
			A (cm^2)	C (cm^2)	%	A (m^2)	C (m^2)	%
El Pardo	6.03a (±0.15)	14.06a (±0.53)	183.52a (±16.93)	24 774.53	0.17 (±0.02)	11.51a (±0.71)	1 553.79	1.06 (± 0.07)
Rancho Acopinalco del Peñón	4.96b (±0.11)	13.25a (±0.11)	167.11a (±17.77)	22 560.47	0.0015 (±0.0002)	3.76b (±0.26)	508.24	0.35 (± 0.009)

A = Average; C = Cumulative. Different letters indicate significant values.

Table 5. Results of the *t*-student tests comparing the dasometric parameters of the measured trees.

Dasometric parameter	*t*	g.l.	*P*
Height	5.65	268	< 0.001
DBH	1.08	268	0.27
Basal area	0.66	268	0.50
Crown cover	9.32	268	< 0.001

Static life tables

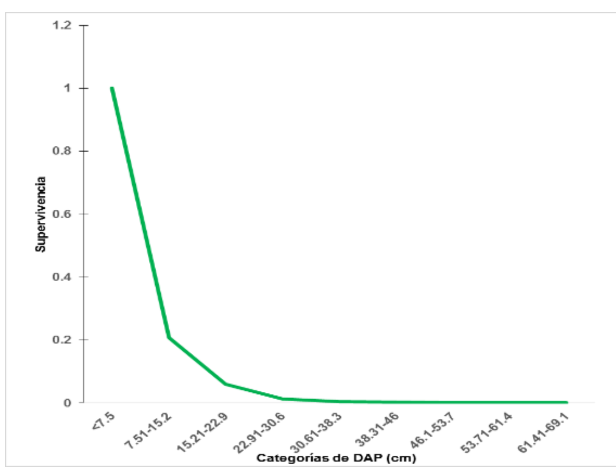
In the joint static life table (data from both sites), the analysis of the mortality rate showed highest survival to be in category 8 (Table 6).

Table 6. Static life table of the two studied sites.

Category	DBH category Interval (cm)	n_x	l_x	d_x	q_x	k_x	e_x
1	<7.5	1 303	1	0.7920	0.79	0.68	0.792
2	7.51-15.2	271	0.2080	0.1481	0.71	0.54	0.905
3	15.21-22.9	78	0.0599	0.0468	0.78	0.66	0.910
4	22.91-30.6	17	0.0130	0.0077	0.59	0.38	1.382
5	30.61-38.3	7	0.0054	0.0023	0.43	0.25	1.642
6	38.31-46	4	0.0031	0.0015	0.50	0.3	1.5
7	46.1-53.7	2	0.0015	0.0008	0.50	0.3	1.5
8	53.71-61.4	1	0.0008	0	0	-	1.5
9	61.41-69.1	1	0.0008	0.0008	1	-	0.5

n_x = Number of individuals; l_x = Survival rate; d_x = Proportion of dead organisms between intervals x and x+1; q_x = Mortality rate); k_x = Mortality intensity; e_x = Life expectancy.

The highest mortality rate was recorded in category 1 (< 7.5 cm) with 79 % of deaths, followed by category 3 (15.21 to 22.9 cm). Individuals in the range 30.61 to 38.3 cm had the highest value for life expectancy; while the lowest value was in category 9 (61.41 to 69.1 cm) (Table 6). The survival curve was a type III curve, in which the trajectory drops suddenly at the juvenile stages and stabilizes in the longer-lived categories (Figure 1).



Supervivencia = Survival; *Categorías* = Categories.

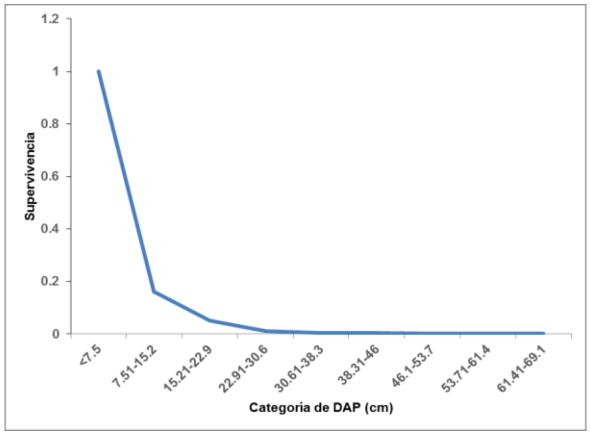
Figure 1. Survival curve of *Juniperus deppeana* Steud. at the two study sites.

In the static life table for EP, the most severe mortality (84 %) was recorded in specimens with diameters < 7.5 cm —since only 16.1 % of the individuals passed on to the next category—, and in category 3 with 80 % (Table 7); therefore, the highest survival occurred in individuals from categories 5, 7 and 8. The highest life expectancy was found in category 7 (Table 7; Figure 2).

Table 7. Static life table of the *El Pardo* site.

Category	DBH category interval (cm)	n_x	l_x	d_x	q_x	k_x	e_x
1	< 7.5	1 057	1	0.8382	0.84	0.792	0.734
2	7.51-15.2	171	0.1618	0.1097	0.68	0.492	0.950
3	15.21-22.9	55	0.0520	0.0416	0.80	0.7	0.9
4	22.91-30.6	11	0.0104	0.0066	0.64	0.44	1.5
5	30.61-38.3	4	0.0038	0.0000	0	0	2.25
6	38.31-46	4	0.0038	0.0028	0.75	0.6	1.25
7	46.1-53.7	1	0.0009	0	0	-	2.5
8	53.71-61.4	1	0.0009	0	0	-	1.5
9	61.41-69.1	1	0.0009	0.0009	1	-	0.5

n_x = Number of individuals; l_x = Survival rate; d_x = Proportion of dead organisms between intervals x and x+1; q_x = Mortality rate); k_x = Mortality intensity; e_x = Life expectancy.



Supervivencia = Survival; *Categorías* = Categories

Figure 2. Survival curve of *Juniperus deppeana* Steud. at the *El Pardo* site, in the municipality of *Tlaxco*, *Tlaxcala*.

At RAP, the highest mortality was found in categories 2 (77 %) and 3 (73.9 %), while life expectancy was highest in category 4. The curve was also type III, which shows that several of the junipers in juvenile stages declined, and that there are no individuals in the larger size categories (Figure 3).

Table 8. Static life table of the *Rancho Acopinalco del Peñón* site, in the municipality of *Tlaxco*, *Tlaxcala*.

Category	DBH category interval (cm)	n_x	l_x	d_x	q_x	k_x	e_x
1	<7.5	246	1	0.5935	0.5935	1.03	1.040
2	7.51-15.2	100	0.4065	0.3130	0.7700	1.222	0.83
3	15.21-22.9	23	0.0935	0.0691	0.7391	0.883	0.934
4	22.91-30.6	6	0.0244	0.0122	0.5000	0.778	1.166
5	30.61-38.3	3	0.0122	0.0081	0.6667	0.477	0.833
6	38.31-46	1	0.0041	0.0041	1	-	0.5
7	46.1-53.7	0	-	-	-	-	-
8	53.71-61.4	0	-	-	-	-	-
9	61.41-69.1	0	-	-	-	-	-

n_x = Number of individuals; l_x = Survival rate; d_x = Proportion of dead organisms between intervals x and x+1; q_x = Mortality rate); k_x = Mortality intensity; e_x = Life expectancy.

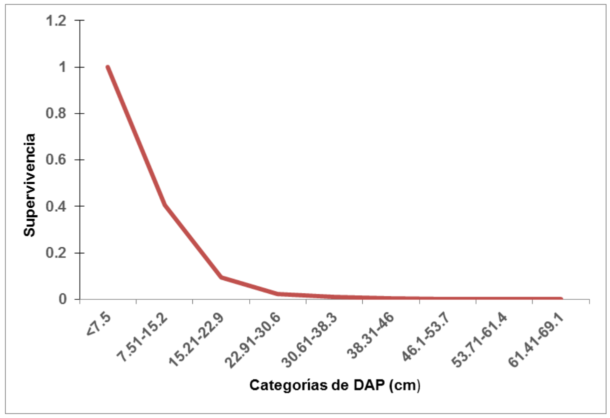


Figure 3. Survival curve of the *Rancho Acopinalco del Peñón* site.

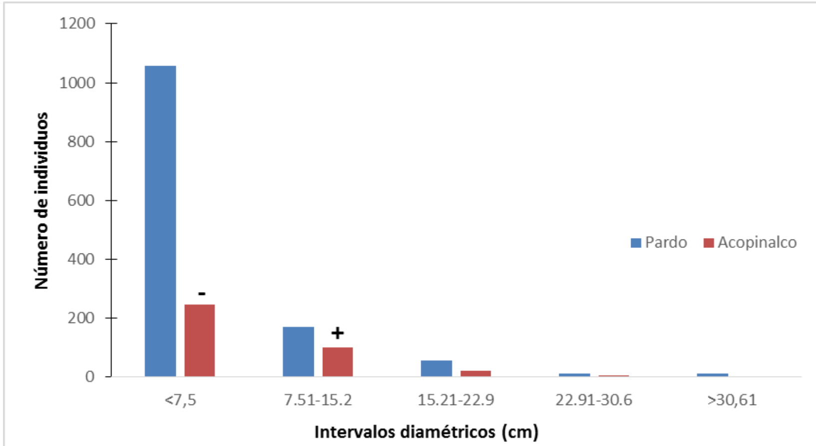
Land size structure

Statistical analyses indicate that the size structure differed among the sampling sites (X^2 = 45.94, g.l. = 4, P < 0.001). The standardized residue test showed significant differences in the frequencies of the first diameter categories of RAP (Table 9); i.e., fewer individuals with a diameter < 7.5 cm were identified than expected at random. The opposite was observed in the junipers of the diameter range of 7.51 to 13.4 cm, where a larger number of such individuals was found than was expected (Figure 4).

Table 9. Standardized residue test results when comparing the size structures of the studied sites.

Diameter interval (cm)	Site	
	El Pardo	*Rancho Acopinalco del Peñón*
< 7.5	1.48	-5.11*
7.51-13.4	-1.39	4.80*
13.41-19.3	-0.34	1.17
19.31-25.2	-0.29	0.98
> 25.21	-0.09	0.30

*= Significant results (P < 0.05).



Número de individuos = Number of individuals*; Intervalos diamétricos* = Diametric categories.

(+) = More individuals were found than expected at random

(-) = Fewer individuals were found than expected at random

Figure 4. Size structure of the *Juniperus deppeana* Steud. populations in the two studied sites.

Relationship between the dasometric parameters and plot slope and orientation

No significant relationships were identified between the dasometric variables and the slope and orientation of the plots (Table 10). Likewise, there was no relationship between these variables and density.

Table 10. Linear-angular correlations between dasometric variables *vs*. slope and orientation.

Correlation	nr^2_{al}	***P***
Density *vs* slope	1.46	0.48
Height *vs* slope	0.02	0.99
Tree cover *vs* slope	0.88	0.64
DBH *vs* slope	0.16	0.92
Density *vs* orientation	0.83	0.66
Height *vs* orientation	0.09	0.63
Tree cover *vs* orientation	1.99	0.36
DBH *vs* orientation	0.15	0.92

Of the relationships between the tree size variables, only the ratio of the DBH to the coverage was significant (Table 11).

Table 11. Ratio of certain dasometric parameters to the DBH (P < 0.05).

Ratio	**Correlation coefficient *R***	***P***
DBH / height	- 0.0362	0.883
DBH / crown cover	0.7801	< 0.001
Height / crown cover	0.2154	0.376

Discussion

The mean values of the dasometric parameters were higher at EP (Table 3), notwithstanding that the total basal area by area of all plots was higher at RAP, and that the crown coverage in the total area was relatively higher at EP (Table 2). The results of the *t*-Student test of mean dasometric variables, with n= 135 in both sites, did not exhibit significant differences in DBH or in basal area (tables 4 and 5); however, significant differences in height and crown cover were evident (Table 5). Hernández *et al.* (2013) described that in a regular temperate forest with over 80 years of forest management and with selection felling cycles, the density of

Juniperus sp. specimens decreases. Likewise, the FM influences the diversity and composition of the tree stratum, as well as the basal area. In fact, this variable increases in exploited species such as *Pinus* spp., whereas in *Juniperus* spp. it varies over the years, but is lower than in taxa of commercial interest (15.21 m^2 ha^{-1} *vs* 0.27 m^2 ha^{-1}, respectively). In contrast, at EP, where forest management is practiced using the *Tlaxco* Method (clear cuts and reforestation), the presence of junipers is sparse and a basal area of 3.07 m^2 ha^{-1} is observed.

Martínez *et al.* (2007) calculated an average height of 6 ± 0.18 m, and an average coverage of 27 ± 2.26 m^2, for *J. deppeana* individuals in an unmanaged forest, that was similar to that of EP, although higher than the values recorded at RAP (unmanaged plot) (Table 4). This may be the result of grazing activities and the selective extraction of *J. deppeana* for firewood and furniture production that take place in that particular plot. On the other hand, and consistent with the present study (Table 11), Martínez *et al.* (2007) do not find a significant association between cover and height ($F_{1, 28}$ = 4.2, r^2 = 0.09, P> 0.05); thus showing that there is no relationship between the tree size variables (Martínez *et al.*, 2007).

Solís *et al.* (2006) reported that there is no notable difference in DBH or height of *J. deppeana* trees subjected to different silvicultural practices (thinning *vs*. selection fellings) in a pine-oak forest in *Sierra de la Candela*, *Durango* —6 m *vs* 5 m (average height), and 12.33 cm *vs* 12.75 cm average DBH-. This contrasts with the results documented herein, for, although there was no significant difference in DBH at EP *vs* RAP, there was a significant difference in height. Furthermore, in the plot under the thinning silvicultural treatment, there is a higher dominance of *Pinus leiophylla* Schiede ex Schltdl. & Cham. as the taxa with lower economic value, such as *J. deppeana*, are targeted in the fellings; wherea the plot with selection treatment focused on *P. leiophylla* as the most important commercial taxon, allows the opening of the canopy, which in turn, favors the development of other species such as junipers. In a forest in Pakistan, Atta *et al.* (2012) recorded that the basal area of *Juniperus excelsa* M. Bieb. varies between the two sampling sites considered, with average values of 90.93 m² ha^{-1} and an interval of 10.91 to 285.07 m² ha^{-1}, which they associate with the anthropogenic disturbance to which one of them is subjected.

In the joint static life table, intense mortality was recorded in the first categories at both sites, although at EP the highest value (84 %) corresponded to category 1 (<7.5 cm); while, at RAP it corresponded to category 2 (77 %). Life expectancy figures were higher in categories 7 and 4, in both localities. This is consistent with the results obtained by Ayerde and López (2006), who recorded that a larger size of *J. flaccida* individuals increases survival in the sites both with and without selective fellings and grazing.

On the other hand, in Spain, Otto *et al.* (2005) report high intra-specific competition for water between *J. turbinata* individuals, and therefore, a large percentage of dead adults, which in turn influence the mortality of seedlings growing under the canopy. Likewise, few adults were observed at either EP or at RAP. Notwithstanding, the type III survival curve implies a notorious mortality of young trees, which may result from a greater susceptibility at early developmental stages to unfavorable environmental factors and competition for resources (Spurr and Barnes, 1992). In fact, Ayerde and López (2006) observed a higher mortality in *J. flaccida* seedlings that are established from July to October, during the dry period (February to March). Therefore, given the high mortality rate and the scarcity of adult individuals, it is likely that younger trees will eventually disappear as well (Zhao *et al.* 2017). In this regard, Moinuddin *et al.* (1990) report that anthropogenic disturbance in a forest in Pakistan impacts on the size class gaps and the low density of *J. excelsa* seedlings, and conclude that without adequate management populations of this taxon will eventually become threatened. On the other hand, although in both plots (EP and RAP) there was a high mortality of young individuals, it is likely that the difference observed in seedling density (individuals < 7.5 cm) (tables 7 and 8) is related to silvicultural management activities *vs* anthropogenic disturbance.

In the study conducted at EP and RAP, the size structure differs between the sampling sites, consistently with what is documented in the literature (Otto *et al.*, 2005; Ayerde and López, 2006; Pérez *et al.*, 2007). At RAP, there were fewer individuals than expected with a DBH < 7.5 cm, and more in category 2 (7.51-15.2 cm). However, the data are similar to those provided by Otto *et al.* (2005), who report a higher density of individuals with lower DBH and height.

In relation to stands with *J. flaccida*, Ayerde and López (2006) report that the density of the size categories below 10 cm DBH (seedlings, juveniles and pre-breeding) is higher in the plot with selective extraction and grazing; whereas in the present study, in the site without timber extraction, there is a higher number of individuals in the diameter categories above 10.1 cm (adult individuals), which could imply that the opening of clearings created by management favors the establishment of this species.

The results obtained in the present research show that EP had a higher density compared to RAP for all categories, meaning that the disturbance caused by cuts, such as the clear cuts, opens larger spaces, which favor the invasion of pioneer species (Spurr and Barnes, 1992). In this respect, *J. deppeana*, is an early-appearing taxon (Ern, 1973). In contrast, Moinuddin *et al.* (1990) found that anthropic disturbance decreases the density of young *J. excelsa* individuals. Furthermore, this may be associated with the results from the standardized residue test that showed significant differences in the frequencies of the first diameter categories of RAP, since fewer individuals were identified with a diameter < 7.5 cm than expected at random; while, in the diameter interval of 7.51 to 13.4 cm, more individuals than expected were observed. This can be explained by both natural and anthropogenic disturbances (fire in 1998, grazing and extraction of junipers for firewood and furniture) to which the forest at RAP has been subjected (Moinuddin *et al.*, 1990; Fitter and Jennings, 1975; Milios *et al.*, 2007); within this context, *J. deppeana* is a species favored by the periodic appearance of fires (Conafor, 2007).

In the present study, the relationship between the dasometric characteristics and the slope and orientation were not significant; however, Aguilar (2019) argues that the latter two are associated with abundance. These features, together with the soil type, the geological substrate, the geoforms, solar radiation, temperature, and precipitation influence the structure, composition, distribution and regeneration of forests (Challenger, 1998; Alba *et al.*, 2003; González, 2003).

Although no significant correlations were found between the density and tree size variables, a significant relationship between DBH and coverage was established (Table 11). Hernández *et al.* (2018) point out that in a temperate forest under sustainable forest management, the basal area of the site is linked to the density, which is a general process that occurs in forests, since high density results in a greater competition among individuals, leading to a reduced basal area per individual (Spurr and Barnes, 1992). However, this analysis was not carried out at the study sites, since no significant differences were obtained in the basal area between the individuals of EP and those of RAP (Table 5). On the other hand, Bailey and Dell (1973) show that in forests there is a high correlation between DBH, height and volume, which is why these variables are used in forests under management in order to design models that estimate volume and extraction costs (Bailey and Dell, 1973), notwithstanding trees with the same diameter in a forest stand do not necessarily have the same height (López *et al.*, 2003). Within this context, no significant relationship was obtained between DBH and height in individuals of EP or RAP (Table 11).

Conclusions

The behavior of the *Juniperus deppeana* populations exhibits a high loss of young individuals, which poses a risk to its natural regeneration. In fact, there are differences in some structural characteristics such as height and crown cover in the two studied plots, that may reflect historic differences in forest use (management (EP) *vs*. grazing and extraction of *J. deppeana*, without any kind of management, for firewood and furniture making (RAP).

Despite the fact that junipers in both localities show the same demographic behavior —a high decline in juvenile stages and a reduced number of adult individuals—, the highest values for survival and life expectancy occur in different diameter categories. Also, size structures between plots differ significantly. In fact, there is a higher density of juniper seedlings at the managed *vs*. the unmanaged sites. However, there is no significant relationship in either plot between the dasometric variables (DBH, height, tree cover, density) with regard to slope and orientation.

Finally, although the specimens at the site subjected to forest management exhibit superior dasometric characteristics, further long-term studies are warranted, where differences between the study sites can be contrasted under a more comprehensive approach, that include diverse micro environmental variables and other structural characteristics, in order to determine prospects for the conservation of this temperate forest associated species in Mexico.

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Conflict of interests

Laura Gabriela Herrerías Mier works in the Editorial Committee of *Revista Mexicana de Ciencias Forestales*; therefore, she did not participate in the editorial process of the manuscript.

Contribution by author

Laura Gabriela Herrerías Mier: field work, data analysis, and drafting, revision and editing of the manuscript; María Cecilia del Carmen Nieto de Pascual Pola: original idea, technical advice, revision and editing of the manuscript.

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