DOI: 10.29298/rmcf.v14i79.1352

Research Note

Diversidad y análisis germinativo de especies arbóreas y arbustivas de interés ecológico en un área incendiada

Diversity and germination analysis of tree and shrub species of ecological interest in a burned area

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Fecha de recepción/Reception date: 8 de marzo de 2023.
Fecha de aceptación/Acceptance date: 22 de julio de 2023.

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Abstract

The vegetation of an ecosystem can be degraded by forest fires; which are caused by human or natural actions and generally reduce the diversity and composition of species, as well as their natural regeneration. This work was carried out in a temperate forest degraded by forest fires in the *El Tejocote* Natural Protected Area, *Santiago* municipality, *Nuevo León* State. The objectives were to calculate the Importance Value Index, analyze species diversity and determine the percentage of germination. Sampling was carried out in 10 random plots of 1 000 m^2. The Importance Value Index (*IVI*), diversity indexes (Margalef, Shannon-Weiner and Simpson) and the germination percentages were determined for each species. *Pinus teocote* had the highest *IVI* (45.5 %), it was also the most dominant, covering 69 % of the sampled area. *Quercus laeta* had 25 % *IVI* and was the most abundant of all species (39 %). *Agave scabra* and *Arbutus xalapensis* had *IVIs* of 7.9 % and 6.9 %, respectively; both were classified as shrubs. A low diversity was obtained in all the sites sampled; the average values were: Margalef (0.74), Shannon-Weiner (0.46), and Simpson (0.77). The highest germination percentages were presented by *Pinus pseudostrobus* (97.40 %) and *Agave scabra* (84 %). The difference in the germination capacity of taxa could change the diversity and species composition of the El *Tejocote* community after its degradation by fire.

Key words: Natural Protected Area, temperate forest, degradation, germination, forest fire, Importance Value Index.

Resumen

La vegetación de un ecosistema puede ser degradada por los incendios forestales; estos se originan por acciones humanas o de manera natural y por lo general reducen la diversidad y composición de especies, así como su regeneración natural. El presente trabajo se desarrolló en un bosque templado degradado por incendios forestales en el Área Natural Protegida El Tejocote, municipio Santiago, Nuevo León. Los objetivos fueron calcular el Índice de Valor de Importancia, analizar la diversidad de especies y determinar el porcentaje de germinación. El muestreo se realizó en 10 parcelas al azar de 1 000 m^2. El Índice de Valor de Importancia (*IVI*), índices de diversidad (*Margalef*, *Shannon-Weiner* y *Simpson*) y los porcentajes de germinación se determinaron para cada especie. *Pinus teocote* tuvo el mayor *IVI* (45.5 %), también fue la más dominante al cubrir 69 % de la superficie muestreada. *Quercus laeta* tuvo 25 % de *IVI* y fue la más abundante de todas las especies (39 %). *Agave scabra* y *Arbutus xalapensis* tuvieron *IVI* de 7.9 % y 6.9 %, respectivamente; ambas se clasificaron como arbustivas. Se obtuvo una baja diversidad en todos los sitios muestreados, y los valores promedio fueron: *Margalef* (0.74), *Shannon-Weiner* (0.46) y *Simpson* (0.77). Los porcentajes de germinación más altos los presentaron *Pinus pseudostrobus* (97.40 %) y *Agave scabra* (84 %). La diferencia en la capacidad germinativa de los taxones podría cambiar la diversidad y composición de las especies de la comunidad El Tejocote después de su degradación por incendio.

Palabras clave: Área Natural Protegida, bosque templado, degradación, germinación, incendio, Índice de Valor de Importancia.

Subject development

Temperate forests provide a variety of ecosystem services, and posess high biodiversity (Prieto-Amparán *et al.*, 2019). Forest degradation negatively affects their functional and structural characteristics (Vásquez-Grandón *et al.*, 2018), it refers to processes that result in long-term and drastic changes in the ecosystems (Thompson *et al*., 2013) and is generally associated with a reduction in biomass, changes in the structure and composition of species, as well as in their natural regeneration (Chazdon *et al*., 2008).

Forest fires are considered one of the main natural or anthropogenic factors causing the degradation of temperate forests (Pausas and Keeley, 2009). In Mexico, the fire regime is characterized by its moderate intensity, occurring at intervals of two to ten years (Santini *et al.*, 2019). Some temperate forest (TF) species can benefit from low to moderate fires, because clearing the land stimulates seed release and promotes natural regeneration; however, when fires are severe, the seed viability declines (Rodríguez-Trejo and Fulé, 2003).

Multiple areas of the *Cumbres de Monterrey* National Park (CMNP) have been degraded due to forest fires that have occurred over time (Cantú *et al*., 2013). The level of species diversity and germination capacity after a fire of the *El Tejocote Laguna de Sánchez* community, located in the central zone of the CMNP, is unknown. For this reason, the following objectives were proposed: (1) To describe the ecological importance and diversity of tree and shrub species in a burned area, and (2) To determine the percentage of germination of tree and shrub species surviving after a fire.

The burned site has a surface area of 10 ha, and the geographical coordinates of the center of the area are 25°19'54" N and 100°15'09" W, at an average altitude of 1 905 masl. The average rainfall there is 640 mm, and the average temperature is 13 ºC (Cantú *et al.*, 2013).

A ten percent of the study area was sampled one year after the fire occurred. Ten circular sampling units (SU) of 1 000 m^2 were established, randomly located at a minimum distance of 20 m between sites (Silva-García *et al.*, 2021). Within each SU, all shrub and tree species were recorded in a census and identified; total height, crown diameter and basimetric diameter at 10 cm were measured for each species. The crown diameters were measured with a model TP20ME Truper® longimeter, the basimetric area with a model 283d Forestry Suppliers® diametric tape, and the total height, with a model B084G8TRG9 Nikon® laser rangefinder.

In order to determine the relative ecological value of the species, the relative frequency (*RF*; Equation 1), relative abundance (*RA*; Equation 2), relative dominance (*RD*; Equation 3) and Importance Value Index were calculated (*IVI*; Equation 4). The *IVI* value was divided by three to standardize an interval of 0 to 100, as the maximum value is 300 when the *RF*, *RA*, and *RD* are added together (Manzanilla *et al*., 2020). The equations for their calculation were as follows:

$$RF = \left(\frac{n}{N}\right) \times 100 \qquad (1)$$

Where:

RF = Relative frequency of the species

n = Number of the SU where the species is present

N = Total number of SUs

$$RA = \left(\frac{n}{N}\right) \times 100 \qquad (2)$$

Where:

RA = Relative abundance per species

n = Number of individuals of the species

N = Overall number of all the species

$$RD = \left(\frac{i}{N}\right) \times 100 \qquad (3)$$

Where:

RD = Relative dominance of the species

i = Crown area of the species

N = Overall crown area of all the species

$$IVI = \frac{\sum_{i=1}^{n}(RA_i, RD_i, RF_i)}{3} \qquad (4)$$

Where:

IVI = Importance Value Index

RA_i = Relative abundance per species

RD_i = Relative dominance of the species

RF_i = Relative frequency of the species

The indexes to measure species diversity were: (1) Margalef (D_{Mg}; Equation 5), whose values above 5 indicate high diversity, while values below 2 suggest low diversity (Margalef, 1972), (2) Simpson's complement (Λ; Equation 6), the range of whose values fluctuates between 0 and 1, high diversity is associated with values close to 1, and a value close to 0 indicates a site with low diversity (Soler *et al.*, 2012; Salmerón *et al.*, 2017), and (3) Shannon-Weiner (H'; Equation 7), whose values range from 0.5 to 5, values above 3 indicate high diversity, while values below 2 denote the opposite (Somarriba, 1999). The equations used to calculate the diversity indexes were as follows (Moreno, 2001):

$$D_{MG} = \frac{S-1}{nl\ N} \qquad (5)$$

Where:

D_{Mg} = Margalef diversity Index

S = Number of species present

nl = Natural logarithm

N = Total number of individual

$$\Lambda = \sum pi^2$$

$$Simpson's\ complement = 1 - \sum pi^2 \qquad (6)$$

Where:

λ = Simpson Index

pi = Abundance according to species *i*

$$H' = -\sum_{i=1}^{S} p_i \times nl\ (p_i)$$

$$p_i = {n_i}/{N} \quad (7)$$

Where:

H' = Shannon-Wiener Index

Pi = Proportional abundance of the species

S = Total number of the species

nl = Natural logarithm

n_i = Number of individuals of species *i*

N = Total number of individuals

An analysis of the percentage of germinated seeds was carried out; the experiment consisted of the following: (1) Collecting seeds from living individuals after the fire, (2) Identifying seeds with no apparent damage, (3) Performing buoyancy tests to detect empty seeds, (4) Applying a pre-germinative process depending on the type of seed: (i) *Pinus* L. and *Quercus* L. were immersed in water for 24 hours, (ii) *Juniperus* L. seeds were placed in 100 % sulfuric acid for 15 minutes, while (iii)

Agave L., *Arbutus* L. and *Rhus* L. underwent no treatment (Antonio *et al.*, 2020), and (5) Sowing 144 seeds of each of the seven identified species in a 288-cavity model ch288 GLL® semi-rigid plastic container.

A completely randomized design distributed in four replications (36 seeds per replication) was used; the response variable was germination, and seven treatments were considered for each of the tree and shrub species. For the germination data, a Shapiro-Wilk normality test was performed (González-Estrada y Cosmes, 2019), and no normality was found ($p \leq 0.00097$). Therefore, a Kruskal-Wallis test was performed to determine the presence of differences between treatments (McKight y Najab, 2010); the comparison between the means of the different species was carried out by means of a Mann-Whitney U test (McKight y Najab, 2010).

The taxa present in the study area were *Pinus teocote* Schltdl. & Cham. (twisted leaf or Aztec pine), *Pinus pseudostrobus* Lindl. (smooth-bark Mexican pine), *Juniperus flaccida* Schltdl. (Mexican juniper), *Quercus laeta* Liebm*.* (white oak), *Rhus virens* Lindh*. ex* A. Gray (evergreen sumac), *Arbutus xalapensis* Kunth (Texas madrone), and *Agave scabra* Ortega (rough *agave* or *maguey*).

The white oak was the most abundant species (Table 1), which is related to the behavior of other species of the same genus (*Quercus*) that survived after the severe fires in *Chipinque* Ecological Park (Alanís-Rodríguez *et al*., 2011). The most dominant tree species was the Aztec pine (Table 2); this agrees with what has been reported in other temperate forests in the state of *Nuevo León* with fire damage, where *Pinus* is the most dominant tree over all other species (Alanís-Rodríguez *et al.*, 2011). The most frequent tree species were *Pinus teocote* and *Quercus laeta* (Table 1); this behavior is normal in this type of ecosystems because in other temperate forests of the *Sierra Madre Occidental* with different environmental conditions and floristic compositions, the frequency percentages for pines and oaks are similar to those obtained in the present research (Hernández-Salas *et al.*, 2013). Both species registered a higher *IVI* (Table 2); this relationship differs from the one reported in *Chipinque* Ecological Park after a fire, where *Quercus* had a higher *IVI* compared to the value of *Pinus* (Alanís-Rodríguez *et al*., 2011). However, this coincides with what was reported by Méndez *et al.* (2014) in a fire-affected TF in the *Sierra Madre de Guerrero*, where the *IVI* of *Pinus radiata* D. Don was high, while that of *Quercus glaucescens* Bonpl. was low.

Table 1. Ecological indicators of tree and shrub species.

Species	**Abundance**		**Dominance**		**Frequency**		***IVI***
	***N* ha^{-1}**	***RA***	**m^{2} ha^{-1}**	***RD***	***N*/Site**	***RF***	
Pinus teocote Schltdl. & Cham.	280	32.18	5816.08	69.91	9	34.62	45.57
Quercus laeta Liebm.	340	39.08	956.37	11.49	7	26.92	25.83
Agave scabra Ortega	100	11.49	78.45	0.94	3	11.54	7.99
Pinus pseudostrobus Lindl.	50	5.75	875.71	10.53	2	7.69	7.99
Arbutus xalapensis Kunth	40	4.6	390.44	4.69	3	11.54	6.94
Rhus virens Lindh. *ex* A. Gray	40	4.6	32.77	0.39	1	3.85	2.95
Juniperus flaccida Schltdl.	20	2.3	170.09	2.04	1	3.85	2.73
Total	870	100	8 319.92	100	26	100	100

RA = Relative abundance; *N* ha^{-1} = Number of individuals per hectare; *RD* = Relative dominance; m^{2} ha^{-1} = Crown cover in square meters per hectare; *RF* = Relative frequency; *N*/Site = Number of sites where the species is present; *IVI* = Importance Value Index.

Table 2. Species diversity indexes.

Sampling unit	**Margalef Index**	**Simpson's Complement**	**Shannon-Weiner Index**
1	0.40	0.49	0.68
2	0.42	0.30	0.47
3	0.91	0.37	0.68
4	0.48	0.50	0.69

5	0.62	0.32	0.50
6	0.00	0.00	0.00
7	0.62	0.48	0.67
8	1.74	0.78	1.56
9	0.80	0.65	1.08
10	1.44	0.72	1.32
Average	0.74	0.46	0.77

One year after the fire, species diversity indices indicate low values in *El Tejocote* (Table 2), consistently with the findings of Méndez *et al.* (2014) and Méndez *et al.* (2018), who also cite low values for the Margalef and Shannon-Weiner indices in a burned temperate forest of the *Sierra de Guerrero*.

Significant differences were obtained between the germination of shrub and tree species (H=17.42, Hc=17.62, p=0.0015). Pine species had contrasting germination percentages (Table 3); similar values have been documented for *Pinus pseudostrobus* in *Michoacán* State (Sáenz *et al.,* 2011) and for *P. teocote* in Veracruz State (Ramírez, 2000). The low germination of *Quercus laeta* (Table 3), can be associated with the fact that *Quercus* seeds are recalcitrant and lose their viability quickly due to fast desiccation (Wawrzyniak *et al*., 2022).

Table 3. Germination percentage of tree and shrub species.

Species	Common name	Germination percentage
Pinus pseudostrobus Lindl.	Smooth-bark Mexican pine	94.4±10.09a
Agave scabra Ortega	*Maguey*	84.00±7.96a
Pinus teocote Schltdl. & Cham.	Aztec pine	31.9±3.49b
Rhus virens Lindh. *ex* A. Gray	Evergreen sumac	10.40±1.32c

Quercus laeta Liebm.	White oak	7.60±0.74c
Arbutus xalapensis Kunth	Texas madrone	0±0
Juniperus flaccida Schltdl.	Mexican juniper	0±0

The letters indicate differences between treatments.

Agave scabra reached a high germination percentage (Table 3), which has been recorded in several *Agave* species (average germination of 91 %) under different environmental conditions (Campos *et al.*, 2020; Castillo *et al*., 2022). The low germination of *Rhus virens* and the null germination of *Juniperus flaccida* and *Arbutus xalapensis* suggest a change in the scarification used: For *J. flaccida* it is proposed to increase the exposure time to sulfuric acid to 5 hours (Martínez-Pérez *et al.*, 2006), as well as cold stratification (Yucedag *et al.* 2021). A similar treatment is recommended for *R. virens* and *Arbutus xalapensis*, but with sulfuric acid exposure times of 30 minutes (Olmez *et al*., 2007).

Acknowledgments

The authors are grateful to the *Consejo Nacional de Humanidades*, *Ciencia y Tecnología* for granting Aldo Tovar-Cárdenas a master's degree scholarship, and to the inhabitants of the community of *El Tejocote*, *Santiago* municipality, *Nuevo León*, for allowing this research.

Conflict of interest

The authors declare that they have no conflicts of interest.

Contribution by author

Homero Gárate-Escamilla: development of the manuscript and statistical analysis; Aldo Tovar-Cárdenas: interpretation of results; Enrique Jurado-Ybarra and Mauricio Cotera-Correa: review of the manuscript; Eduardo Alanís-Rodríguez and Maritza Gutiérrez-Gutiérrez: data analysis.

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