ECOSISTEMAS Y RECURSOS AGROPECUARIOS

Effect of cattle and wildlife exclusion areas on the survival and growth of *Pinus culminicola* Andresen & Beaman

Efecto de las áreas de exclusión para ganado y fauna silvestre en la sobrevivencia y crecimiento de *Pinus culminicola* Andresen & Beaman

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ABSTRACT. In 1997, a restoration of *Pinus culminicola* was established under three exclusion areas: E1 = cattle plus small mammal exclusion, E2 = cattle exclusion and E3 = no exclusion (free range), in the Cerro El Potosi Protected Natural Area, located in Nuevo León, Mexico. The objective of this study was to determine the survival rate and the increase in diameter and height of *Pinus culminicola* individuals at three and 17 years after planting. The results show differences between 2000 and 2014 in survival rate and diameter and height growth in the three exclusion areas; E1 and E2 recorded higher averages. The main causes of mortality in this species are attributed to extreme weather conditions and the damage caused by cattle and small mammals.
Key words: Degradation, exclusion, *Pinus culminicola*, restoration, survival

RESUMEN. En 1997 se estableció una restauración de *Pinus culminicola* en tres áreas de exclusión: E1 = exclusión de ganado mayor + exclusión de mamíferos menores, E2 = exclusión de ganado mayor y E3 = sin exclusión, en el Área Natural Protegida Cerro El Potosí, Nuevo León, México. El objetivo fue determinar el porcentaje de sobrevivencia y el incremento en diámetro y altura de individuos de *Pinus culminicola* a tres y 17 años de plantación. Los resultados muestran diferencias entre el 2000 y 2014 en el porcentaje de sobrevivencia y crecimiento en diámetro y altura en las tres áreas de exclusión, en E1 y E2 se tuvieron los mayores promedios. Las causas principales de mortalidad de *P. culminicola* se atribuyen a las condiciones climáticas extremas, al daño ocasionado por el ganado y los mamíferos menores.
Palabras clave: Degradación, exclusión, *Pinus culminicola*, restauración, sobrevivencia

INTRODUCTION

Ecological restoration is defined as the process of assisting the recovery and reestablishment of an ecosystem that has been degraded, damaged or destroyed (SER 2004) by anthropogenic activities that affected its diversity and dynamics (Jackson *et al.* 1995). It is defined as a long-term vision, based on a set of actions in which natural succession is assisted and facilitated (Ruiz and Mitchell 2005) for the regeneration and recovery of a habitat (Celentano *et al.* 2011), as well as the structure and function of the ecosystem (Barrera and Ríos 2002). Restoration represents a way to improve human well-being in the long term, through the recovery of soil productivity and natural capital, as well as the provision of goods and services (Chazdon 2008).

Pinus culminicola Andresen et Beaman is an endemic species that is located in the Sierra Madre Oriental, with an altitudinal distribution between 3 300 and 3 450 masl. It is listed as a species in danger of extinction by NOM-059-SEMARNAT-2010

(SEMARNAT 2010) and endangered (EN) by the Red List of Internationally Threatened Species. This species is distributed in a limited area of the Cerro El Potosí Protected Natural Area (PNA) in Galeana, Nuevo León and Sierra La Viga in Ramos Arizpe, in the state of Coahuila, Mexico (Favela 2010).

In 1978, a series of wildfires devastated a wooded area of the Cerro El Potosí PNA, resulting in a 34% decrease in the area occupied by this vegetation (García *et al*. 1999). In 1998, several wildfires decreased the *Pinus culminicola* distribution area, causing the area evaluated by Beaman and Andresen in 1966 (106 ha) to decrease to its present size of no more than 30 ha, where the population of *Pinus culminicola* occurs in small groups with overmatured individuals and therefore a low production of germplasmic material (Jiménez *et al*. 1999).

After wildfires in priority management areas, such as Natural Protected Areas, it is common for ecological restoration measures to be implemented immediately (Beghin *et al*. 2010). The most common practices worldwide are the planting of woody plants (Jiménez *et al*. 2005) and the placement of soil retention works (Myronidis *et al*. 2010). A loss of the natural regeneration of the diverse species of conifers located within the PNAs is due to the wild fauna and the grazing of domestic livestock, specifically in the Cerro El Potosí PNA where the presence of cattle does not allow the development of natural regeneration of *P. culminicola*, being a limiting factor for the development and distribution of this species (Jiménez *et al*. 2005). Therefore, the objective of this study was to determine the survival rate and the increase in diameter and height of *P. culminicola* individuals at three and 17 years after planting in the Cerro El Potosí Protected Natural Area.

MATERIALS AND METHODS

Study area

The study area is located at 3 300 masl in the Cerro El Potosí Protected Natural Area, located in the southeastern region of the state of Nuevo León, Mexico (Figure 1). This mountainous massif corresponds to the Sierra Madre Oriental, which is located between the Gulf Coastal Plain and the Mexican Altiplano. Due to its high percentage of endemic species, and its geographic and topographical distribution with respect to other mountains, it has been the center of study of several authors (Beaman and Andresen 1966, Jiménez *et al*. 1996).

Evaluation of exclusion areas

In December 1997, a restoration of *P. culminicola* was carried out in excluded and non-excluded areas, establishing three different exclusion area systems: E1 = cattle plus small mammal exclusion, E2 = cattle exclusion and E3 = no exclusion (free range). Each exclusion area contained 110 individuals at an approximate density of two plants per 10 m2 (2,000 plants ha). It is important to note that due to the cost of establishing this type of restoration, no repetitions of the same exclusion areas were made.

The survival of *Pinus culminicola* was determined to estimate the proportion of live individuals with respect to planted trees, by means of formula 1 (CNF 2013).

$$P = \left(\frac{\sum_{i=1}^{n} a_i}{\sum_{i=1}^{n} m_i} \right) * 100$$

Where P is the proportion of live individuals, a_i the number of live trees at site i and m_i the number of trees planted at site i.

The diameter at neck height (DNH) and the total height (h) of the individuals were also measured at two different times: 3 and 17 years (year 2000 and 2014). The measurement of these dendrometric parameters is based on the existence of seedling development as there is a growth in diameter and height (Jiménez *et al*. 1996).

Statistical analysis

To determine the existence of significant differences in the variables total height and diameter at the neck among the exclusion areas, the mean values were estimated. Once the data complied with the criteria of normality and homoscedasticity,

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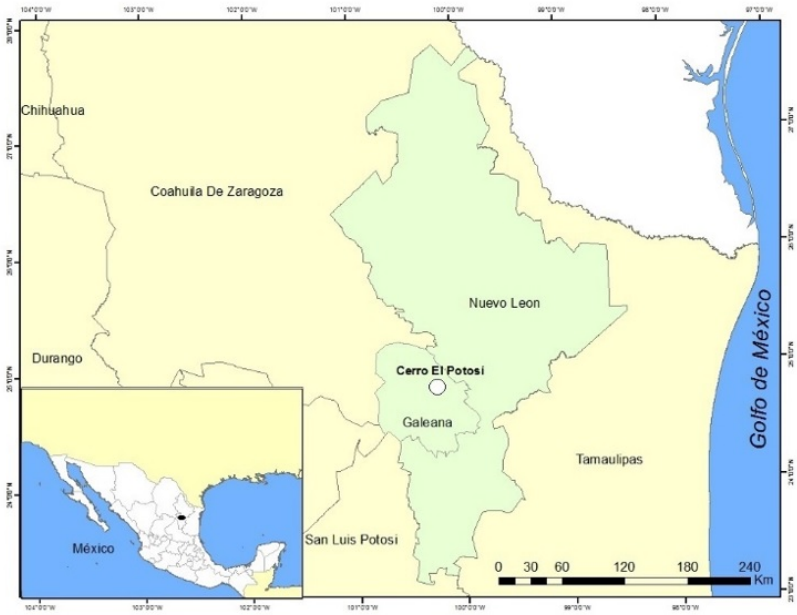

Figure 1. Location of the Cerro El Potosí Protected Natural Area, Nuevo León, Mexico.

a one-way analysis of variance was performed ($p \leq 0.05$). In case of obtaining significant differences, a comparison of means analysis was conducted using Tukey's HSD test.

RESULTS AND DISCUSSION

Survival

When performing the analysis of the survival variable as a function of the different exclusion areas and based on two different periods (3 and 17 years), E1 and E2 showed the highest survival rates for 2000 with 56 and 54, while E3 (without protection) had 28% ($p = 0.008$). After 17 years, survival in the three exclusion areas decreased ($p = 0.056$) to 27, 10 and 12% for E1, E2 and E3, respectively (Figure 2). The decrease in the exclusion areas is due to factors such as extreme climatic conditions typical of the study area, such as low temperatures, strong winds, scarce rainfall, low relative humidity, little soil depth and loss of edaphic material. The survival rates obtained in E3 for 2000 and E1 for 2014 are similar to those obtained by Alanís-Rodríguez *et al.* (2008) who report 23% survival in a restored pine-oak forest area, while Lamb and Gilmour (2003) and Celentano *et al.* (2011) indicate that it is important and necessary to protect the seedlings from any type of external disturbance such as fires and animals, so that the development processes occur naturally, although, according to Meli (2003), they vary depending on the climate, the type of soil, the existing vegetation, and the history and management of the land (Zimmerman *et al.* 2000, López-Barrera *et al.* 2007). Therefore, restoration strategies must take into account all possible obstacles (Holl *et al.* 2000, Gil 2001).

Height

The average height of the *Pinus culminicola* seedlings showed differences within the exclusion areas, being higher in E1 in both evaluation years (2000 and 2014). For 2000 the E1 seedlings averaged a height of 13.4 cm, while E2 and E3 had 10.3 and 10.9 cm, respectively ($p = 0.011$) (Figure 3). In 2014 the average height values for E1, E2 and E3 were 57.07, 39 and 34.2 cm, respectively ($p = 0.003$) (Figure 3).

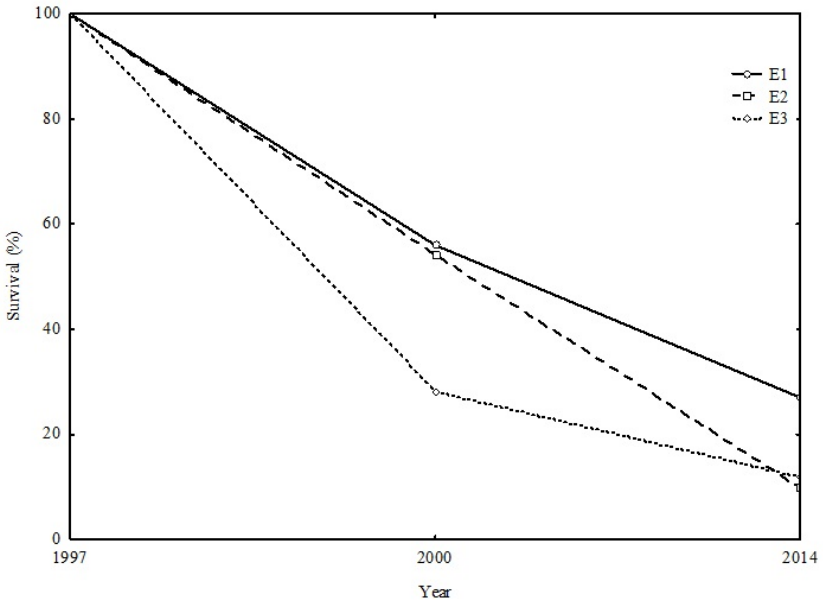

Figure 2. Survival of *Pinus culminicola* seedlings in relation to exclusion areas. E1 = cattle and small mammal exclusion, E2 = cattle exclusion and E3 = no exclusion.

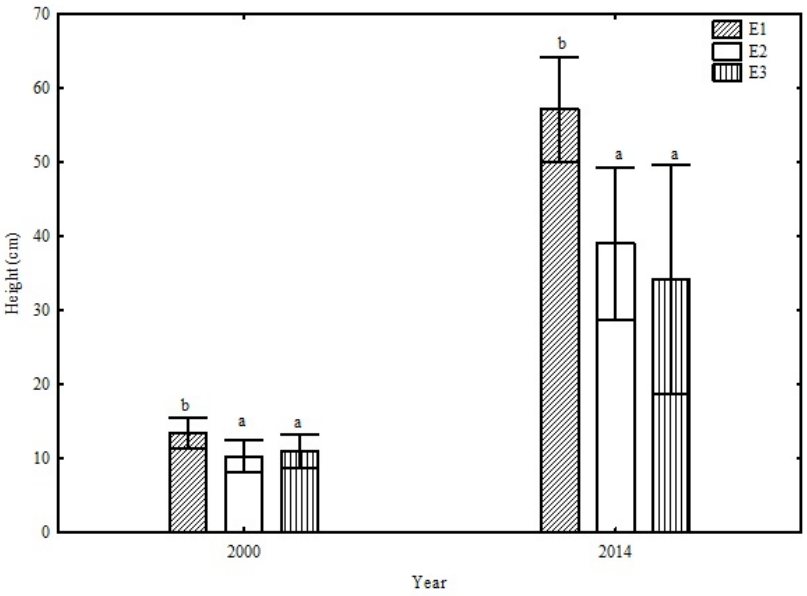

Figure 3. Average height of *Pinus culminicola* by exclusion area. Significant differences ($p < 0.05$). E1 = cattle plus small mammal exclusion, E2 = cattle exclusion and E3 = no exclusion.

Diameter at neck height

There are differences between the neck diameters of the seedlings in the different exclusion areas in 2000 ($p = 0.004$); the average diameter in E1 and E2 was 2.17 and 1.56 cm, respectively, while E3 had a lower value of 0.9 cm. The neck diameters also showed a difference in 2014 ($p = 0.027$), having values of 4.36, 3.36 and 1.99 cm for E1, E2

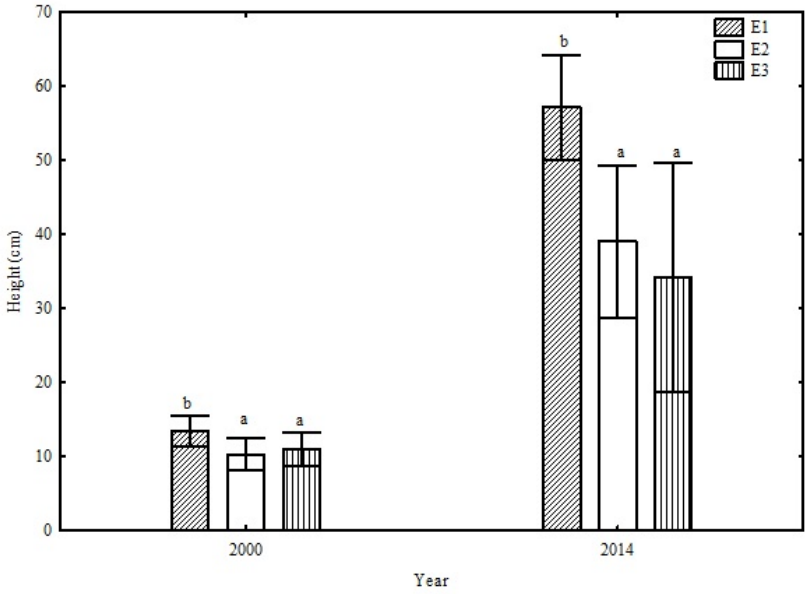

Figure 4. Average diameter of *Pinus culminicola* by exclusion area. Significant differences ($p < 0.05$). E1 = cattle plus small mammal exclusion, E2 = cattle exclusion and E3 = no exclusion.

and E3, respectively (Figure 4).

The increase in both plant diameter and height coincides with the findings of Aguirre *et al*. (2003) who report that in a *Pinus culminicola* ecosystem the height of the trees varies between 0.9 and 2.9 m and the diameter between 5.3 and 17.3 cm, but likewise the seedlings were prone to grazing; therefore, and according to Jiménez *et al*. (1999), livestock is one of the constraints on the development of the plants, although on the other hand Guzmán and Navarro (2005) mention that grazing is a modeling factor in Mediterranean ecosystems, which can cause severe damage to some ecosystems while in others it is a useful management tool (Ferrer and Broca 1999).

The exclusion area against cattle and small mammals proved to be efficient, as it doubles the survival rate, diameter and total height values. This is attributed to the fact that in the areas without exclusion there was the presence of large and small cattle, resulting in trampling of individuals; likewise, rodents caused damage to the apical buds of the plants, which predisposes them to a lower survival rate. It is important to note that *Pinus culminicola*, due to its shrubby development, does not show the characteristics of other coniferous species, so there is slow development with respect to the dendrometric variables of diameter and height. The results obtained show that the use of seedlings and the application of exclusion areas provide a form of restoration in *Pinus culminicola* shrubland, due to greater survival of the established individuals and the development of the diameter and height of this species endemic to the Sierra Madre Oriental.

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