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Research note

Supervivencia y crecimiento de una reforestación de *Pinus cembroides* Zucc. en el noreste de México

Survival and growth of *Pinus cembroides* Zucc. in Northeastern Mexico

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Abstract

The evaluation of the survival and growth of a *Pinus cembroides* plantation was carried out in the *La Tapona ejido*, *Galeana* municipality, state of *Nuevo Leon*, with the objective of evaluating the effect of individual terraces and ditches in basal diameter, total height, and crown diameter of a 10-year-old plantation. 13 transects (contour lines) for each of the treatments (26 in total) were evaluated using a systematic random sampling design. From each of the transects, information was taken from all individuals, including diameter at 10 cm from the base of the trunk (cm), total height (m) and crown diameter (m). To determine whether there were significant differences in the survival of specie in relation to the different treatments (individual terraces and ditches), an analysis of variance was performed using Student's *t*-test and the Mann-Whitney *U*-test for height, diameter at 10 cm and crown diameter. The results indicate an overall average survival of 52.69 %, while in blind pits it was 53.71 %, and individual terraces it was 51.68 %. However, the tests showed that there were no significant differences in growth of individuals within conservation practices.

Key words: Mortality, sampling, plantation, conservation practices, *t*-test, reforestation.

Resumen

Se estudió la supervivencia y el crecimiento de una reforestación con *Pinus cembroides* en el ejido La Tapona, municipio Galeana, Nuevo León con el objetivo de evaluar el efecto de las terrazas individuales y tinas ciegas en el diámetro basal, altura total y diámetro de copa de una plantación de 10 años. Se evaluaron 13 transectos (en curvas de nivel) de cada uno de los tratamientos (26 en total), mediante un diseño de muestreo sistemático aleatorio. En los transectos se registró la siguiente información de todos los individuos presentes: el diámetro a 10 cm de la base, la altura total (m) y el diámetro de copa (m). Para determinar si existían diferencias

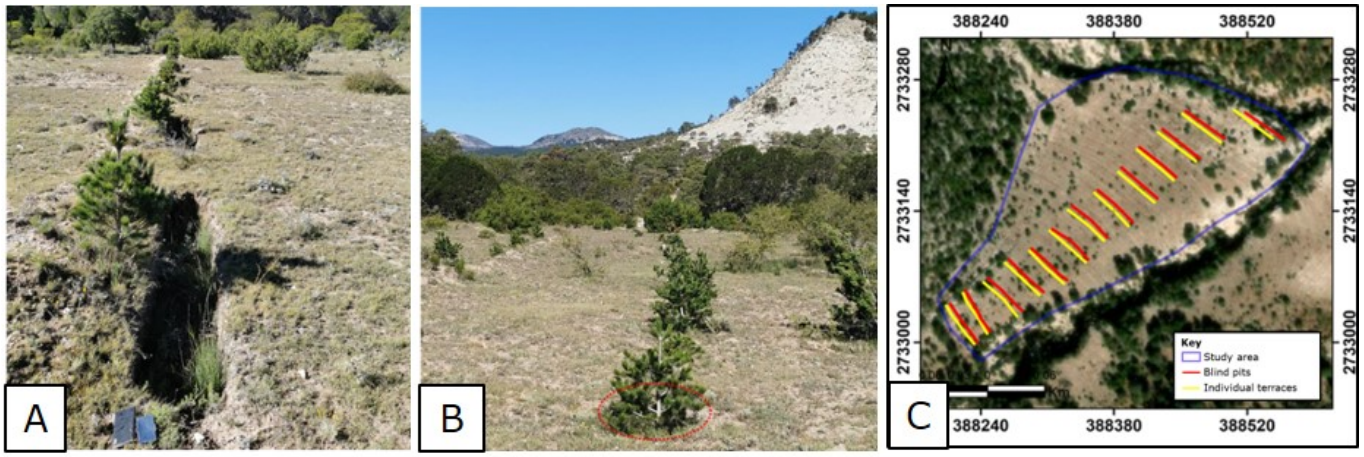
significativas en la supervivencia de la especie con respecto a los diferentes tratamientos (terrazas individuales y tinas ciegas), se realizó un análisis de varianza con la prueba *t* de *Student* y la prueba *U* de *Mann-Whitney* para las variables de altura, diámetro a 10 cm y el diámetro de copa. Los resultados indicaron un promedio general de supervivencia de 52.69 %, mientras que en tinas ciegas de 53.71 % y en las terrazas individuales 51.68 %. Sin embargo, las pruebas determinaron la ausencia de diferencias significativas en el crecimiento de los individuos dentro de las obras de conservación.

Palabras clave: Mortandad, muestreo, plantación, prácticas de conservación, prueba de *t*, reforestación.

Woods are forested areas that support a great biological diversity. In addition, they play an important role in regulating the planet's climate, stabilizing soils and balancing water flows, to name a few functions (ONUAA, 2016). In turn, they provide a variety of environmental goods and services directly and indirectly to the population (Conafor, 2010). The loss of natural resources and ecosystems is a global problem. Mexico is on the list of the top countries with high deforestation rates (Ventura-Ríos *et al.*, 2017).

In 2013, a 6.10 ha *Pinus cembroides* Zucc. plantation was established in *Galeana* municipality, state of *Nuevo León*, to contribute to the increase in forest area and counteract deforestation. Before its establishment and as part of the land preparation, soil conservation works were carried out by opening 480 blind pits (ditches) (TC) per hectare and 1 000 individual terraces (TI) also per hectare.

The TCs are a set of excavations interspersed and designed in contour lines (Figure 1A), in order to reduce the length of the water path, capture the runoff water and reduce erosive processes (Conafor, 2023). On the other hand, the TI’s (Figure 1B) main purpose is to retain water from surface runoff to increase the survival and growth of seedlings (Conafor, 2023).



A = Blind pits; B = Individual terraces in the *La Tapona Ejido*; C = 50 m transects (sampling units) in each of the selected contour lines.

Figure 1. Soil conservation works and transects evaluated.

The objective of this study was to evaluate the effect of TCs and TIs on the survival, as well as the growth of the main mensuration variables of a 10-year-old *P. cembroides* plantation in *Galeana*, state of *Nuevo León*, Mexico. It was hypothesized that individuals located in the TI will have higher survival percentages and growth in base diameter, crown diameter and total height than in the TC.

The research was carried out in the *La Tapona ejido* of *Galeana* municipality, state of *Nuevo León*, Mexico. The climate is dry or temperate [BSok(x´)] with an average annual temperature ranging between 12 and 18 °C (García, 2004). Annual precipitation is between 400 and 600 mm; and the predominant soil is of the Leptosol type (INEGI, 1986).

The plantation was carried out with a distance between plants around 2 m and an average separation between contour lines of 5.20 m. Seedlings had an average height of 30 cm.

In 2023, 10 years after the plantation was established, the assessment was carried out. The plantation surface was delimited by field surveys and satellite

images. A random systematic sampling design was followed, in which 13 contour lines were selected from each treatment (blind pits and individual terraces) with a 21 % sampling intensity. A 50 m transect (sampling unit) was established in each selected contour line, because not all of them had the same length (Figure 1C) (Prieto and Goche, 2018).

In each 50 m transect, all *P. cembroides* individuals were considered. In the case of blind pits, there were 12 per transect, and in the individual terraces, 25. Total height (m), crown diameter (m) and base diameter at 10 cm from the ground were measured for each specimen. These measurements were made with a model FA-3M Truper® 3 m tape for total height; crown diameter was measured in two directions (North-South and East-West) with a model 30-088 Stanley® tape measure, while the base diameter was recorded with a model HER-411 Steren® 15 cm digital vernier (Alanís *et al.*, 2020).

To assess survival, live and dead plants were counted (%). Subsequently, the following Equation (Conafor, 2010) was applied to obtain the survival percentage of the *P. cembroides* plantation:

$$p = \frac{\sum_{i=1}^{n} ai}{\sum_{i=1}^{n} mi} \times 100$$

Where:

p = Estimated proportion of living trees (expressed in %)

∑ = Summation of the data according to the variable *a* or *m*

ai = Number of living plants in the transect

mi = Number of established plants in the transect

The basimetric area and crown area per individual were estimated using the base diameter and crown diameter variables (Alanís *et al.*, 2020).

For statistical analysis, a Kolmogorov-Smirnov test was applied with the Lilliefors correction, in order to recognize whether the data met the normality assumptions (Ghasemi y Zahediasl, 2012).

In order to test the null hypothesis (*Ho*) that there are no significant differences between TI and TC in the *P. cembroides* survival, the Student *t* test (α=0.05) was used. For the total height and basimetric and crown area variables, the non-parametric Mann-Whitney *U* test was performed. The data were analyzed using the Statistical Package for Social Sciences statistical program version 13.0 (SPSS, 2009).

Table 1 shows the average values of total height, base diameter at 10 cm from the base, and crown diameter. The height of the specimens indicates a growth of around 30 cm in 10 years.

Table 1. Average values and standard deviation of the tree variables measured in the different treatments, blind tips (TC) and individual terraces (TI).

Variables	Mean and standard deviation	
	TC	TI
Height (m)	0.569±0.260	0.622±0.329
Base diameter ($d_{0.10\ m}$)	1.96±0.886	2.01±1.00
Crown diameter (m)	0.489±0.201	0.513±0.239

The *t* test (α=0.05) showed that there are no significant differences in the survival rate (p=0.471) of *P. cembroides* when comparing the TI and TC, and the Mann-Whitney *U* test, that there are no differences in the variables of height, crown area and basimetric area (Table 2).

Table 2. Mann-Whitney *U* test for blind pits and individual terraces.

	Height	**Crown area**	**Basimetric area**
Mann-Whitney *U* test	11 658.000	12 003.500	12 348.000
Z	-0.918	-0.491	0.064
Sig. asintót. (bilateral)	0.358	0.624	0.949

Z = z value; Sig. asintót. = Asymptotic significance

The average survival rate at 10 years after planting was 52.69 %. The plantation treated with TC presented 53.71 %, while the one treated with TI, 51.68 %, a value that slightly exceeds that recorded by Ortíz-Rodríguez and Rodríguez-Trejo (2008) of 48.8 % in a *Pinus hartwegii* Lindl. plantation three years after its establishment. There the survival was attributed to the protective effect provided by the shrub and herbaceous strata.

Sánchez (2008) evaluated the survival of *Pinus oaxacana* Mirov in two sites with different treatments (reforestation associated with TC, reforestation with prior soil removal [RS] and reforestation with common strain [CC]). The survival rates of TC, RS and CC in Site 1 were 20, 29 and 30 %, respectively. For Site 2, the RS treatment reached 50 % and the TCs at the edge were 20 %. For Site 1, reforestation was not considered successful since the values were less than 50 %. Therefore, the values achieved in this study for the TCs (53.71 %) can be considered acceptable; since the survival percentages in Mexico in 2019 recorded by Coneval (2018) are less than 50 %. Céspedes and Moreno (2010) showed that the *Conafor* survival rates (%) for 2002, 2003, 2004 and 2005 were 49.5, 43.9, 58.3, and 55 %, respectively.

On the other hand, Vásquez-García *et al.* (2016) carried out a survival and mortality evaluation in forest plantations located in three communities of the *Mixteca Alta Oaxaqueña*. This study highlights the survival recorded at 8 and 10 years, with 72.35

and 79.52 %, respectively; the high numbers were attributed to the adequate selection of species and the favorable climatic conditions, characterized by 700-1 000 mm of rainfall, a figure higher than that recorded in this work.

Cotler *et al.* (2013) analyzed the physical and chemical properties of the TI and TC treatments after four years, and determined that both treatments behaved similarly, did not show a change in moisture content and porosity, and with respect to carbon and nitrogen content, the values were lower compared to the control plots.

Ventura-Ríos *et al.* (2017) studied the structure, height, basimetric area and aboveground biomass in three reforested areas of five (R5), 12 (R12) and 14 (R14) years and a reference site (SR). Their conclusions refer that the R5 condition presented the lowest values for the three dimensions. In addition, the comparisons between R12, R14, and the SR only showed significant differences in height and aboveground biomass.

According to the results obtained in the present investigation, the hypothesis is rejected, since no significant differences were observed in the survival and growth of *P. cembroides* individuals planted in both the TC and TI treatment areas. The shallow nature of Leptosol that restricts soil development and root penetration presents challenges. However, *P. cembroides* is a widely used species in dry temperate, arid and semi-arid climates, due to its resistance to low rainfall and its remarkable adaptability to drought conditions since its root system allows it to access water deep in the soil. This condition is reflected in the similarity of height, crown diameter and basal diameter. Possibly, this uniformity is attributed to the fact that in the early stages of development, the studied pine species adapted to the soil conservation works applied in this particular area, and benefited from them.

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Conflict of interest

The authors have no conflict of interest. Eduardo Alanís Rodríguez, in his capacity as Section Editor of the Mexican Journal of Forest Sciences, declares not to have participated in the editorial process of this document.

Contribution by author

Ana Marissa de la Fuente Solís, Eduardo Alanís Rodríguez and María Inés Yáñez Díaz: conception of the research, field work, species identification, data analysis, interpretation of results and writing of the manuscript; Israel Cantú Silva, Wibke Himmelsbach and Miguel Ángel Martín del Campo Delgado: review, interpretation of results and writing of the manuscript; Ana Marissa de la Fuente Solís, Eduardo Alanís Rodríguez and Miguel Ángel Martín del Campo Delgado: general review and writing of conclusions.

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