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Article

Supervivencia y crecimiento de *Pinus pseudostrobus* Lindl., y *Pinus montezumae* Lamb. en diferentes fechas de plantación

Survival and growth of *Pinus pseudostrobus* Lindl. and *Pinus montezumae* Lamb. on different planting dates

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Resumen:

La mortalidad en plantaciones forestales con fines de restauración en la última década (2007 a 2017) ha variado de 40 a 60 % al año de establecida a nivel nacional. La supervivencia y desarrollo de especies de pino y latifoliadas se han afectado por el efecto combinado de la fecha de plantación, la preparación del terreno y la calidad de planta, además de su introducción tardía. El objetivo del estudio que se describe consistió en evaluar la supervivencia, el desarrollo y el crecimiento inicial de *Pinus pseudostrobus* y *Pinus montezumae* establecidas en diferentes fechas de plantación en la Comunidad Indígena de Nuevo San Juan Parangaricutiro, Michoacán. La plantación se estableció en 2013 y se replicó en 2015 bajo un diseño experimental de bloques completos al azar, con cinco fechas de plantación (tratamientos) del 1 de julio al 30 de agosto y cada tratamiento con cuatro repeticiones. Durante tres años se evaluó la supervivencia, el crecimiento en altura y el diámetro a la base de la planta; el análisis de varianza presentó diferencias significativas ($p \leq 0.05$) en la altura y el diámetro. La plantación realizada los días 1, 15 y 30 de julio mostró mayor crecimiento en ambas variables, además de 70 % de supervivencia en las dos especies. El éxito o fracaso de una plantación es resultado de integrar una fecha de plantación correcta, buena calidad de planta y preparación del terreno, junto a condiciones ambientales favorables.

Palabras clave: Crecimiento, desarrollo, fechas de plantación, *Pinus pseudostrobus* Lindl., *Pinus montezumae* Lamb., supervivencia.

Abstract:

Mortality in forest plantations for restoration purposes in the last decade (2007 to 2017) has varied from 40 to 60 % per year after established at the national level. The survival and development of pine and broad-leaved species have been affected by the combined effect of the date of planting, the preparation of the land and the quality of the plant, in addition to its late introduction. The objective of the study here described was to assess the survival, development and initial growth of *Pinus pseudostrobus* and *Pinus montezumae* established on different planting dates in the *Comunidad Indígena de Nuevo San Juan Parangaricutiro, Michoacán*. The plantation was established in 2013 and was replicated in 2015 under a randomized complete block design, with five planting dates (treatments) from July 1st to August 30th and each treatment with four replications. During three years, survival, growth in height and diameter at the base of the plant were evaluated; the analysis of variance showed significant differences ($p \leq 0.05$) in height and diameter. The plantation carried out on July 1st, 15th and 30th showed greater growth in both variables, in addition to 70 % survival in the two species. The success or failure of a plantation is the result of integrating a correct planting date, good plant quality and land preparation, together with favorable environmental conditions.

Key words: Growth, development, planting dates, *Pinus pseudostrobus* Lindl, *Pinus montezumae* Lamb., survival.

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Introduction

The success or failure of plantations in Mexico is strongly linked to climate (Muñoz *et al.,* 2011; Sáenz *et al*., 2011) and other conditions such as the quality of the plant, the planting process and the date of planting (UANL, 2009; UACH, 2010; Semarnat, 2013). Climatic factors can hardly be controlled, but, the technical components can be manipulated. However, at the national level, mortality in forest plantations in the last decade (2007 to 2017) has gone from 40 to 60 % a year after its establishment (UACH, 2007 and 2010; UANL, 2009; Semarnat, 2011a; Conafor, 2017).

Navarro and Palacios (2004) and Palacios (2016) point out that the survival of pine and oak species is affected by the combined effect of the date of planting, the preparation of the land and the quality of the plant; the first is important in the final survival of the first year of the plants established (Royo *et al.,* 2000; Navarro and Palacios, 2004). In works carried out with Mediterranean species (*Pinus pinea* L. and *Pinus halepensis* Miller.), it is recognized that plantations in early dates after the rainy season for the region is defined, assure the success of the survival up to 90%, but an excessive delay at such time, compromises the final survival (Royo *et al*., 2000; Corchero *et al.,* 2002; Navarro *et al.,* 2004; Jinks *et al.,* 2006).

The state of *Michoacán* ranks third in wood production nationwide, the first place in resin production and fifth place in biodiversity (COFOM, 2016). The entity promotes the development of forest plantations of *Pinus, Eucalyptus* and *Cupressus* among the main genera, with conservation and restoration ends or for the planning and execution of management plans (Semarnat, 2011a, 2011b; Semarnat, 2013). The forest extension of the State is equivalent to 3 % of the national territory; 2.2 million ha^{-1} of it are mild-cold weather forests and medium and low tropical forests, where it is estimated that more than 700 thousand ha^{-1} have been lost in the last 20 years (COFOM, 2016). The Indigenous Community of *Nuevo San Juan Parangaricutiro, Mich*. extends over 18 138 ha^{-1}, 10 870 ha^{-1} of which are wooded and the rest, dedicated to different uses.

At present, *P. pseudostrobus* Lindl. and *P. montezumae* Lamb. are the most appreciated species in the forest industry of the region; therefore, it is convenient to study the combined effect of the factors previously indicated at the time of planting with these species. In this context, the objective was to evaluate the survival, development and initial growth in plants of these species established on five different planting dates in the Indigenous Community of *Nuevo San Juan Parangaricutiro, Mich.*

Materials and Methods

Study area

The study area is located in the locations known as *El Tejamanil* and *Huiramo* of the Indigenous Community of *Nuevo San Juan Parangaricutiro* (CINSJP), *Michoacán* state, between 19°24'16.7" North and 102°14'12.7" West, at an average altitude of 2 735 m. They belong to the Transverse Neovolcanic Axis, hydrological region RH: 18 (*Balsas* river) and sub-basin G (*Cupatitzio* river) (INAFED, 2018).

The climate, C (m) (w) big (Köppen modified by García, 1973) is humid temperate with summer rains and <5 % winter rains.

The dominant soil is of the humic Andosol type (INEGI, 2009; UNDP, 2012). The average slope in the sites is 5 %, and they were intended for agricultural use and cattle grazing. The vegetation bordering the plantation sites is made up, mainly, of mixed pine-oak forests; and its most representative conifer species are *P. pseudostrobus* and *P. montezumae*, which have great commercial value in the *Sierra Purhépecha* region.

Characteristics of the plant

The plant was produced in the *El Durazno* forest nursery of the CINSJP. The plant of *P. pseudostrobus* was produced in black polyethylene bag (1 + 1) of 5 × 20 cm and with a volume capacity of 393 mL, the height and diameter at the base of the initial plant was 35.81 cm and 10.01 mm respectively, for the plantation of *P. montezumae*, one-year (1 + 0) plants produced in polystyrene trays of 77 cavities and a volume

capacity of 170 mL, of at least 4 cm in height and 4 mm in diameter were used to the base of the plant. The substrate used in black polyethylene bags was 60 % of oak land (decomposing litter) and 40 % of red soil (*topure*-soil andosol) and for the plant produced in polystyrene trays was a mixture of Sunshine peatmoss (40%), perlite (20 %), insulex vermiculite (20 %) and Osmocote™ (18-6-12) (10 %).

Two plantations were carried out with both species, the first in 2013 and a replica in 2015. The planting of both species was made during the beginning of the rainy season (July-August) in the CINSJP region. The plants were established with the plantation system of common stock 40 × 40 × 40 cm, with a plantation design with real frame, at a spacing of 2 m between plants and rows.

Experimental design and evaluated variables

A randomized complete block design was used in the 2013 plantation and in the 2015 replica. Five treatments were used (five planting dates) and four replications (blocks) per species. Each experimental unit was composed of 25 plants, with a total of 100 individuals per treatment and 500 per species, in a total area for both plantations of 5 200 m^2. The planting dates were July 1 (F1), July 15 (F2), July 30 (F3), August 15 (F4) and August 30, 2013 (F5).

The evaluated variables were the total height of the plant (cm), measured with an Apex model stalk (cm) and the diameter of the base of the plant (mm) was measured with a Neiko type digital vernier; survival (alive or dead), by direct counting.

In *El Tejamanil*, for each date of planting and species, three measurements were made, the first of which was at the end of its establishment and later, at one year, two years and three years of planting; in *Huiramo* only one evaluation was made one year after it was established.

Data analysis

With the total height and diameter at the base of the plant, an analysis of variance was carried out with the STATISTICA program, version 13 (Statsoft, 2017), to determine statistical differences together with the survival data, which were transformed to natural logarithm; the planting date (F1, F2, F3, F4 and F5) was taken as the grouping variable. The mathematical model used was the following:

$$Y_{ij} = M + A_i + B_j + A_i*B_j + E_{ij}$$

Where:

Y_{ij} = Random variable that represents the value of the response in the j^{th} observation of the i^{th} treatment

M = Constant that represents the average response of the *Y* variable

A_i and B_j = Effects of the *i* (*i* = Date: 1, 2, 3, 4 and 5) treatment and of time *j* (*j* = 1, 2 and 3 years)

A_i*B_j = Effect of the interaction of the *i* treatment by the *j* time

E_{ij} = Experimental error (Norman *et al*., 1996)

Simple variance analyzes were performed only when the treatment effect of the previous model was significant. The multiple comparison method used for the classification of means was that of Tukey with 95 % confidence limits.

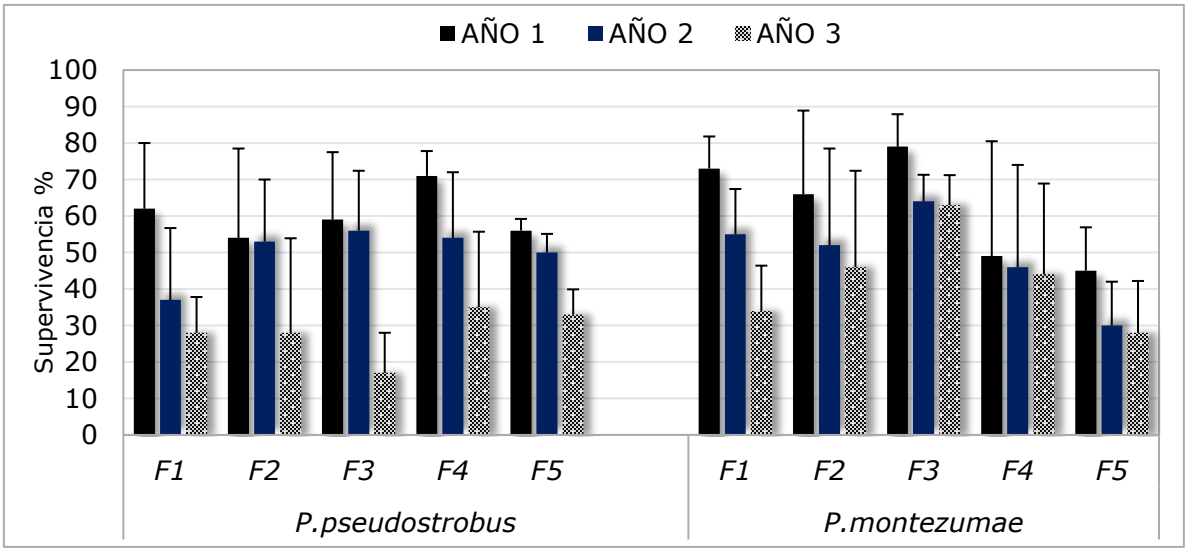
Results and Discussion

Survival

The survival of *P. pseudostrobus* and *P. montezumae* in *El Tejamanil* and *Huiramo* showed no significant differences related to the date of planting ($p \geq 0.05$) in any period evaluated, although the first year of planting in the first site, *P. pseudostrobus* registered 60 % survival for the plants established in July and 65 % in the August ones, differences that kept as such during the second year with 50 % in favor of the early dates (July) and 54 % for late dates (August); finally, in the third year of evaluation, the percentage of survival was 35 % for the late and 30 % for the early. This decrease in survival was mainly due to the attack by Michoacana wild rodent (*Zygogeomys trichopus* Merriam, 1895), -a species subject to protection (P) according to NOM-059-Semarnat-2010-which reduced survival up to 35 % of the first two years after the plantation of both species.

García and Aguilar (1996) cite that these rodents are harmful and one of the main problems of mortality in forest plantations established in the *Sierra Purhépecha, Michoacán*; they cause important economic losses during the first years in forest plantations and agricultural crops (Monroy *et al.,* 2005).

For the *P. montezumae* plantation in *El Tejamanil*, 70 % survival was registered at the evaluation year at early dates and 60 % at late dates; during the second year this percentage remained in favor of the plantation carried out in July with 60%; in the last evaluation, both lapses showed 45 % survival on average (Figure 1), a reduced percentage as a result of the rodent attack.

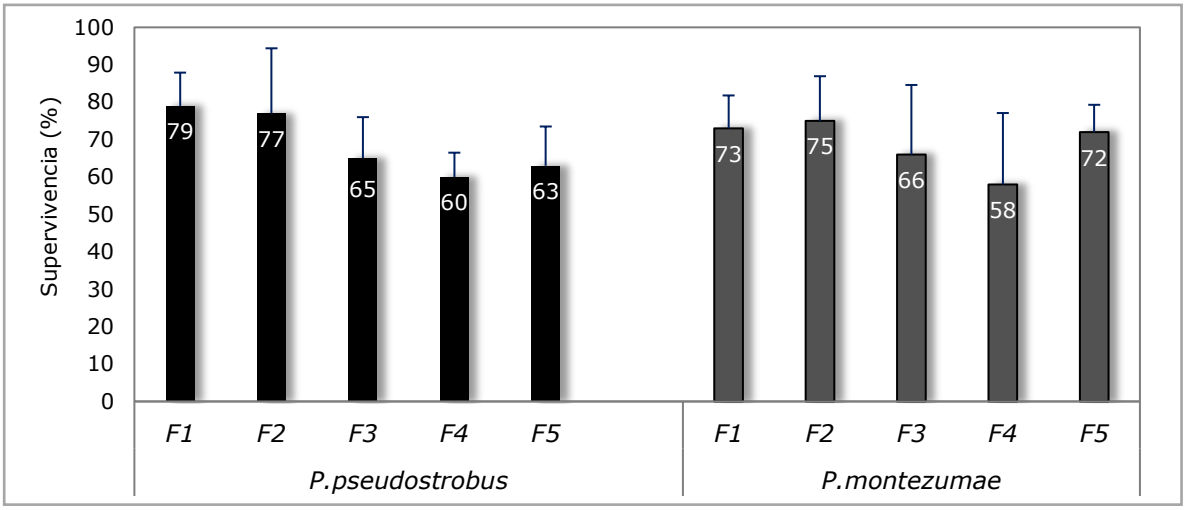


Supervivencia = Survival; *Año* = Year

Figure 1. Survival of *Pinus pseudotrobus* Lindl. and *Pinus montezumae* Lamb. at *El Tejamanil* three years after its establishment with five planting dates (mean ± standard deviation).

In the plantation of *Huiramo*, survival was also 70 % for the studied species in the first year of establishment, with a higher percentage in the early dates (July), compared to the late ones (August) (Figure 2). However, no significant differences attributable to the date of planting were confirmed.

Some studies have addressed the influence of this factor on survival and growth with *Pinus* species, with which the results have been unequal. Royo *et al.* (2000) and Ariza *et al.* (2008) report that there are no significant survival differences when comparing different planting dates with *P. halepensis* Miller., with a logical tendency to decrease from an initial 100 % up to 80 % at the end of the first year.



Supervivencia = Survival

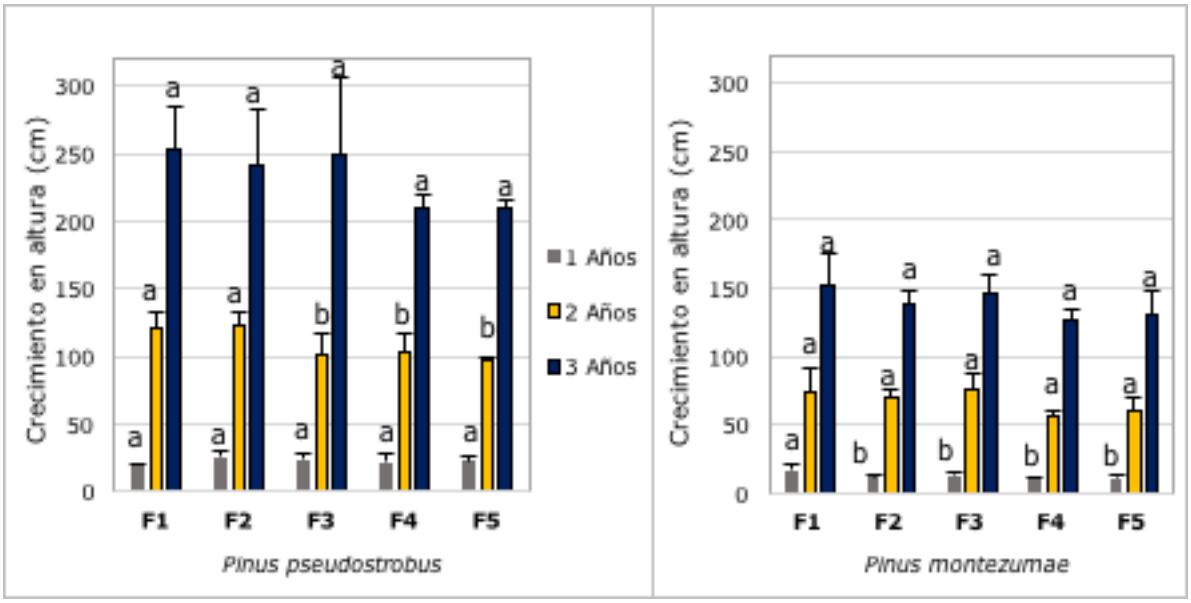
Figure 2. Survival of *Pinus pseudotrobus* Lindl. and *P. montezumae* Lamb. at *Huiramo* one year after establishment with five planting dates (mean ± standard deviation).

However, these results are different from those obtained by Rodríguez (2013), since in a trial with two species of pine identified significant differences between treatments, which were explained by the date of planting. Royo *et al.* (2000) and Navarro *et al.* (2004) have shown the importance of this variable, even considering it as having the greatest influence on the development, growth and subsequent survival of the plantation.

Growth in height

At the *El Tejamanil* site during the three years of evaluation, the statistical differences in growth between planting dates were highly significant ($p < 0.0001$) for both species. The plantations established on July 1st and 15th, 2013 (F1 and F2, respectively) had higher growth in height compared to the other dates; from the first year in *P. montezumae* significant differences were identified ($p \leq 0.01$), since the growth in height was 17.26 ± 5.34 cm on July 1st to 15th ,and 13.91 ± 2.39 cm on August 1st to 30th; in regard to the growth from the initial height of 4 cm, there are

differences of up to 13.26 cm in favor of F1 and F2. On the other hand, for *P. pseudostrobus*, only in the second year of evaluation the height showed differences between treatments ($p \leq 0.02$), in F1 and F2 with a growth of 24.7 cm more against F3, F4 and F5 (Figure 3).



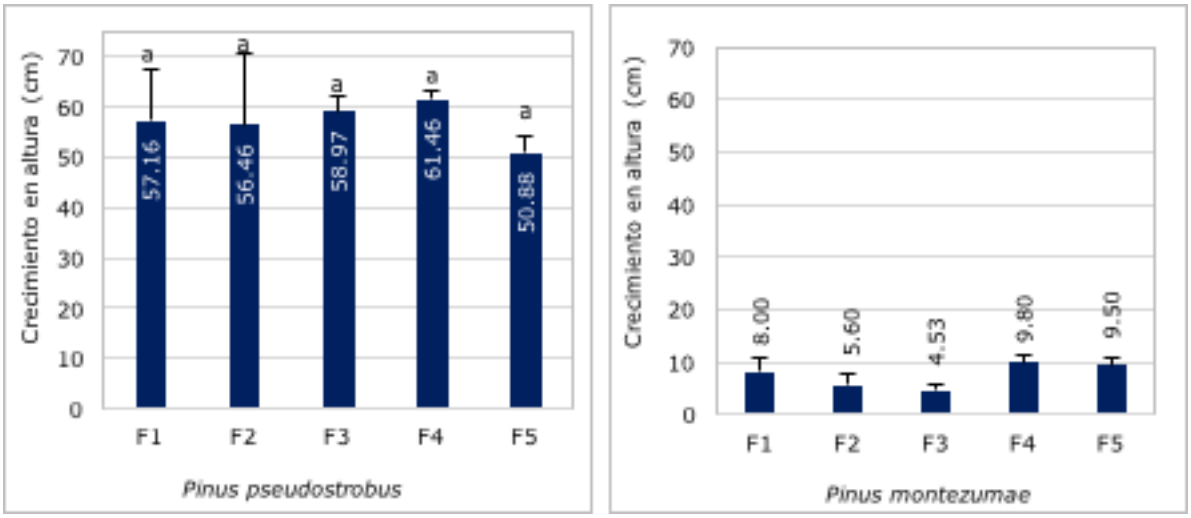
Crecimiento en altura = Growth in height; *Años* = Years.

Different letters indicate significant differences Tukey 95 %, mean ± standard deviation.

Figure 3. Growth in height of *Pinus pseudotrobus* Lindl. and *Pinus montezumae* Lamb. at *El Tejamanil* three years after its establishment in five planting dates.

The differences in growth in each evaluation period indicate that the date of planting had a significant effect on the growth in height for both species and is attributed to having established the plantation in early dates (beginning of rains in July).

In the plantation of *Huiramo*, after a year of evaluation (2016), *P. montezumae* presented significant differences ($p \geq 0.003$) in the growth in height; in the late dates, F4 and F5, the species had the best response, which contrasts with the results obtained in *El Tejamanil*, during the same evaluation (Figure 4).



Crecimiento en altura = Growth in height

Different letters indicate significant differences Tukey 95 %; mean ± standard deviation.

Figure 4. Growth in height of *Pinus pseudotrobus* Lindl. and *Pinus montezumae* Lamb. at *Huiramo* a year after its establishment on five planting dates.

Similar results were reported by Taylor (2007) with *Pseudotsuga menziesii,* after evaluating eight planting dates established from August 2005 to January 2006 in a location of Oregon, USA; he concluded that the height growth of the plantation made in October 2005 (early date for the area) was higher compared to the successive planting dates of November of the same year and of January 2006.

Barber (1989), meanwhile, recorded that the total height of *Larix occidentalis* Nutt seedlings (western maple) was 43 % higher for those planted in the fall (early dates) compared to those in the spring (late dates). Ariza *et al.* (2008) describe that with *P. halepensis*, height growth was higher in plants established in November (early dates) than in January (late dates) and that at the end of the measurement period the differences maintained the same trend, just like in this work. Moraga *et al.* (2000) coincide with the above on the growth in height, since at the end of the first summer, the difference between the plantation with the highest growth of *P. halepensis* (January) and that of the lowest (February) was 8 cm. As in this case, the differences

in height growth increased in the second year and reached more than 40 cm, between planting dates for both species.

Larcher (2003) points out that the growth in height is attributed to the availability of water at the time of establishing the plantation. The absence of significant differences for the growth in height of any of the years evaluated is indicative of low water availability. The analysis of the data showed that the height growth from one year to the next is highly significant ($p \leq 0.0000$), so it should be considered that a forest plantation in its first years, depends on a large number of factors, both climatic as technical; the former can hardly be controlled by man (Sígala *et al.,* 2015) and that is where the choice of the appropriate date of planting lies mainly.

Diameter to the base of the plant

The differences in diameter at the base of the plant between planting dates were significant ($p \geq 0.0001$) in *El Tejamanil* in each year evaluated for both species. In all the measurements, the growth pattern in diameter was the same; the dates of the 1st and July 15th (F1 and F2) showed a growth significantly higher than in August. In the first year of measurement, the differences between the planting dates with the highest growth (July) and those with the lowest growth (August) were 3 mm in both species, which increased in the second year of evaluation (30 mm) and thus until the third when they exceeded 30 mm from one year to the next (Table 1). Only in the second, significant differences were obtained ($p \leq 0.03$) from the diameter at the base of the *P. pseudostrobus* plant, so the growth of the early dates of July is related to the height of the same dates for this species.

Table 1. Mean growth value (standard deviation) in diameter at the base of the plant (mm) of *Pinus pseudostrobus* Lindl. and *Pinus montezumae* Lamb. three years after their establishment in five plantation dates.

Species	Plantation date in 2013 and 2015	Sites			
		El Tejamanil			***Huiramo***
		Year of assessment			
		Year 1 (2014)	Year 2 (2015)	Year 3 (2016)	Year 1 (2016)
Pinus pseudostrobus	July 1st (F1)	17.8 (1.2)	*40.9(2.1)	71.3(4.1)	16.5 (1.2)
	July 15th (F2)	17.5 (1.8)	*39.9 (1.5)	65.8(9.6)	15.1 (3.6)
	July 30th (F3)	16.4 (0.6)	37.8 (2.3)	68.3(4.3)	15.3 (0.5)
	August 15th (F4)	15.4 (2.7)	38.8 (1.6)	66.1(3.9)	14.6 (2.5)
	August 30th (F5)	14.5 (1.3)	37.6 (2.2)	65.1(4.3)	12.5 (0.5)
Pinus montezumae	July 1st (F1)	11.4 (0.5)	33.6 (2.6)	62.5 (4.2)	12.2 (0.3)
	July 15th (F2)	10.6 (0.4)	32.8 (1.3)	59.0 (3.2)	9.9 (0.8)
	July 30th (F3)	*12.0(0.6)	32.8 (1.6)	60.7 (1.2)	10.8 (3.6)
	August 15th (F4)	11.2 (0.5)	30.4 (5.2)	52.3 (3.6)	12.2 (0.6)
	August 30th (F5)	*12.9(1.1)	33.0 (4.0)	56.5 (9.9)	12.2 (1.1)

*****Significant with p ≤0.05.

In the first year, *P. montezumae* also recorded statistical differences (p≤0.002) since the growth of the date of August 30th (late date) exceeded that of July, but the trend in successive years remained in favor of the early dates (Table 1).

In *Huiramo*, no statistical differences were confirmed (p≥0.05) in either of the two species, but it is noted that there is a trend of greater growth in the early dates (July) with respect to August with more 4 mm in favor of the first. In both places, it is observed that the diameter growth at the base of the plant from one year to the next is 45 % more in the July specimens

than in those of August. In terms of growth, the development of plants is largely determined by the evolution of climatic conditions after their establishment (Palacios *et al*., 2008; 2009); thus, they are conditions that cannot be manipulated (Sigala *et al.,* 2015). The water supply was adequate for the plants incorporated at an early date (F1 and F2) since in the region, the rainy season starts in July.

These results coincide with those obtained by Mateos *et al.* (2008) when comparing two planting dates of *P. halepensis*; where the growth differences in height and diameter were significant ($p < 0.05$) since the growth in diameter was greater in the plantation in November (early dates) with respect to January (late dates). Rodríguez (2013) under greenhouse conditions, points out that late sowing with *P. patula* and *P. greggii* Engelm., can reach significant differences in the same variables. However, there are contrary cases in which significant differences in the date of planting, both early and late, can reach their maximum development, provided that the climatic conditions are favorable during the first year of their establishment, as shown by the evaluations made during the three years in this case.

Conclusions

The date of planting of both sites and for the conditions tested, did not show any significant effect on the survival of the plantation with *Pinus pseudostrobus* and *Pinus montezumae*, although there is a tendency for a higher percentage of live plants in early planting dates (F1 and F2). regarding the late August plantation (F4 and F5).

The plants established on July 1st, 15th and 30th exhibited a greater significant influence on the growth in height and diameter at the base in both species; in the first dates of planting, the meteorological conditions of the locality favored its development.

It is confirmed that the success or failure of a plantation is the result of integrating factors such as the date of planting, the quality of the plant and the preparation of the land, without forgetting the environmental conditions that exert influence; when carrying out future plantings with these species in the CINSJP, it should be considered

that in early planting dates, the percentage of survival is higher, in addition to the growth in both height and diameter at the base of the plant, are related to dates of early planting for this locality.

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Rubén Barrera Ramírez: planning of the research study, field data collection, data analysis and writing of the document; Ricardo López Aguillón e Hipólito Jesús Muñoz Flores: planning of the research study, data analysis and review of the manuscript.

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