Survival, growth and carbon content in a forest plantation established after a clear-cutting in Durango, Mexico

Jesús Alejandro Soto-Cervantes[1], Artemio Carrillo Parra[2], Rodrigo Rodríguez Laguna[3], José Javier Corral-Rivas[4], Marín Pompa-García[4], Pedro Antonio Domínguez Calleros[4]

[1] Programa Institucional de Doctorado en Ciencias Agropecuarias y Forestales, Universidad Juárez del Estado de Durango, Durango, México

[2] Instituto de Silvicultura e Industria de la Madera, Universidad Juárez del Estado de Durango, Durango, México

[3] Instituto de Ciencias Agropecuarias, Universidad Autónoma del Estado de Hidalgo, Tulancingo, Hidalgo, México.

[4] Facultad de Ciencias Forestales, Universidad Juárez del Estado de Durango, Durango, México

Corresponding Author:
Pedro Antonio Domínguez Calleros
Río Papaloapan y Blvd. Durango S/N Col. Valle del Sur, Durango, Durango, 34000, México
Email address: pdomingc@hotmail.com

Abstract

Background. Forest plantations play an important role in carbon sequestration, helping to mitigate climate change. In this study, survival, biomass, growth rings and annual carbon content storage were evaluated in a mixed *Pinus durangensis* and *P. cooperi* plantation that was established after a clear-cutting. The plantation is eight years old and covers an area of 21.40 ha.

Methods. Sixteen sites of 100 m² were distributed randomly. At each site, two trees distributed proportionally to the diametric categories were destructively sampled (one per tree species). Two cross-sections were cut from each tree: The first at the base of the stump and the second at 1.30 m. The width of tree rings of the first cross-section was measured using a stereoscopic microscope with precision in microns (μm). The year-by-year basal diameter of each tree was recorded and biomass and carbon content was estimated using allometric equations.

Results. The estimated survival was 75.2%. The results of the ANOVA showed significant differences between the year-by-year width records of tree rings, the highest value corresponding to the fifth year. The average carbon sequestration per year is 0.30 kg for both studied tree species.

Conclusions. *P. durangensis* and *P. cooperi* plantations adapt and develop well in Durango forests when they are established in areas that are subjected to clear-cutting.

Key words: Growth rings, biomass, basal diameter.

Introduction

In addition to the multiple benefits that forest ecosystems provide to society, forests can capture significant amounts of greenhouse gases (GHG), particularly carbon dioxide *(Benjamín & Masera, 2001; Aguirre-Calderón & Jiménez-Pérez, 2011; Martínez et al., 2016; González-Cásares et al., 2019)*. However, the vegetation cover is not always adequate due to inappropriate forest management, and so the establishment of trees is necessary. Whatever the purpose of this action, reforestation (forest plantations) is an excellent alternative to mitigate high atmospheric concentrations of CO_2 and, at the same time, reducing global warming *(van Minnen et al., 2008; López-Reyes et al., 2016; Patiño et al., 2018; Ramírez-López & Chagna-Avila, 2019)*. Proper soil management also contributes significantly to the expansion of the carbon sink in the terrestrial biosphere *(Zambrano, Franquis & Infante, 2004; Caviglia, Wingeyer & Novelli, 2016; Halifa-Marín et al., 2019)*.

The Mexican forests have been considered as diverse in terms of tree species *(Medrano et al., 2017)* and have great potential as a carbon sink, and therefore are considered essential to assess carbon content in programs designed to mitigate global warming *(Pompa-García & Sígala-Rodríguez, 2017; Domínguez-Calleros et al., 2017)*. Frequently 50% carbon concentration of total biomass has been assumed, however, this statement leads to inaccurate carbon estimates, due to variation of the carbon concentration between arboreal components and tree species *(Pompa-García & Yerena-Yamalliel, 2014; Wang et al., 2015; Hernández-Vera et al., 2017)*. Forest plantations of one or two species stand out as the most efficient way to increase carbon sequestration capacity of forest regions, because forest owners plant normally fast-growing tree species *(Reyes, León & Herrero, 2019)*.

Pinus durangensis and *P. cooperi* are species frequently used in forest reforestations in the state of Durango *(Prieto et al., 2016)*. However, successful forest plantation requires planting quality seedlings with optimal growth potential. Thus, foresters need to use seedlings with plant attributes (i.e. shoot height, stem diameter, root mass, shoot to root ratio, drought resistance, mineral nutrient status) that favor the best chance of successful establishment once they are field planted *(Grossnickle, 2012; Pérez-Luna et al., 2019, 2020)*. The use of quality seedlings favors success in plantations under climate change conditions *(Vallejo et al., 2012)*. In Mexico 57% of mortality is caused by the poor quality of the plant *(Prieto et al., 2016)*, also another important factor are the deficiencies that occur during the planting process *(Burney et al., 2015),* for example, if the strain becomes too deep the plant will suffocate and if the strain becomes shallow, the roots could be left on the surface and the plant will dehydrate, in addition, covering the stem with too much soil reduces the vigor of the plant and makes difficult its access to water *(CONAFOR, 2010)*.

For the proper management of forests in Mexico, including areas planted with the main commercial tree species, different silvicultural systems are employed in order to ensure the regeneration of the site: The Mexican Irregular Forest Management Method (MMOBI) and the Silvicultural Development Method (MDS) *(Solís et al., 2006; Pérez-Verdín et al., 2009; Pérez-Rodríguez et al., 2013)*. The former is used in forest stands with a high tree species richness, and the latter in stands dominated by one or two tree species of pine *(Hernández-Díaz et al., 2008)*. Moreover, in areas covered with little or no slope, the use of a clear-cutting as a regeneration method can be also used. It is characterized by having periodic crops, determined by commercial rotations *(Gadow, Sánchez & Aguirre, 2004)*, and their regeneration can be natural or artificial. If the regeneration is artificial, then the use of fast-growing species is preferable.

85   Although clear-cutting can be used successfully in Mexican forests, this silvicultural method is
86   still considered inappropriate, because complete tree removal of an area may cause degradation
87   of forest components such as soil, water quality, fauna, etc., at least at the beginning of the
88   forestry process *(Keenan & Kimmins, 1993; Hernández, Jaeger & Samperio, 2017; Monárrez-*
89   *González et al., 2018)*. However, its use has economic advantages. On the one hand, an
90   intermediate economic income is possible, through silvicultural interventions (thinnings); on the
91   other, the reduction of competition improves the dimensions of the trees that remain standing and
92   the CO_2 sequestration increases *(Rodríguez-Larramendi et al., 2016; Rodríguez-Ortiz et al.,*
93   *2019)*. Investigations that address the survival behavior and the carbon content of mixed *Pinus*
94   *cooperi* and *P. durangensis* plantations in the initial phase are scarce *(Návar et al., 2004)*. The
95   study of these aspects is important for the proper management and conservation of forest
96   plantations in Mexico. As a hypothesis of this study, we consider that plantations of *Pinus*
97   *cooperi* and *P. durangensis* established after clear-cuttings, show high levels of survival and
98   growth, and contribute efficiently to carbon sequestration. Thus, the objectives of this work were
99   to evaluate survival, the width of tree rings and carbon content in a plantation of *Pinus*
100   *durangensis* and *P. cooperi* at a site exposed to clear-cutting in the State of Durango, Mexico.
101
102   **Materials & Methods**
103   **Study area**
104   This study was conducted in the private property "Las Veredas", municipality of San Dimas,
105   Durango, Mexico, belonging to the Compañía Silvícola Chapultepec, S. DE R. L. DE C. V., in
106   the coordinates of the site are: 24° 20' 40" N and 105° 51' 20" W (Fig. 1). The climate is
107   temperate with a brief rainy season during the summer months (C_W), and the temperature ranges
108   between -3 and 18 °C *(García, 2004)*. The topography is characterized by hills, with slopes
109   ranging from soft to medium (0 to 50%). The area occupied by the clear-cutting has a slope of
110   9% and an altitude of 2803 m asl. The average annual rainfall recorded during the period 2010 to
111   2018 was 1,034.5 mm (this value was recorded by the weather station in the town of Vencedores,
112   located 15 km away from the study area). Rainfall occurs in the months of June, July, August
113   and September; The first frost occurs in October and the last frost occurs in June; snowfall
114   occurs most frequently in the months of December and January *(FSC & SmartWood, 2002)*.
115   The vegetation is characterized by mixed coniferous and broadleaved forests. The dominant pine
116   species are: *Pinus durangensis* Martínez, *P. cooperi* Blanco, *P. teocote* Schl. and *P. strobiformis*
117   Engelm. The main oak species are: *Quercus rugosa* Née and *Q. sideroxyla Bonpl*, in addition
118   some species of the genera *Juniperus, Arbutus*, and *Alnus* are also part of the forest composition
119   *(González-Elizondo et al., 2012)*.
120   **Figure 1**
121
122   **Forestry background**
123   Before the clear-cutting, the stand had a stocking of 220.4 m³ ha⁻¹ of trees of the following
124   genera: *Pinus, Quercus, Juniperus* and *Arbutus (PMF, 2010)*. The trees were harvested at the
125   beginning of 2010 on an area of 21.40 ha. Months later, during the rainy season, the plantation
126   was established with seedlings of *P. durangensis* and *P. cooperi* (it was not possible to know the
127   proportion, but *P. durangensis* was planted in greater quantity). The plantation was produced
128   with germplasm collected from trees growing in natural stands next to the study area. Land
129   preparation consisted of clearing, scattering and applying the controlled burning of forest waste.
130   To improve soil conditions, the ground was plowed using a D-6 track-type tractor, equipped with

131   a ripper, breaking equidistant lines (2 m) at a depth of 60 cm, in the perpendicular direction to
132   the slope. The seedlings were 12 months old with a height of between 15 and 20 cm and a
133   diameter at the base of the stem of 5 mm. They were planted using the common strain method in
134   a "real frame" at a spacing of 2 × 2 m to generate a density of 2,500 seedlings ha^{-1}.
135
136   **Field Evaluation**
137   Sixteen (16) circular sites of 100 m^2 were established, distributed completely randomly to
138   evaluate survival according to the recommendations of *CONAFOR (2013)*. In addition to
139   survival, variables such as diameter (cm) and height (m), were measured using a Vernier and
140   hypsometer (Vertex V®), respectively. The sample implied the demolition of 32 trees, distributed
141   proportionally to the diametric categories (16 of each tree species). Two cross-sections were
142   obtained from each tree (over-bark and under-bark): one was cut at the base of the tree and the
143   second one at 1.3 m above ground.
144   The cross-sections were labeled, dried and polished, and the measurement of each growth ring
145   was subsequently performed using a stereomicroscope with precision in μm. This process was
146   carried out in the dendroecology laboratory at the Facultad de Ciencias Forestales of the
147   Universidad Juárez del Estado de Durango. The year-by-year width of each tree ring was
148   estimated by the average of four-way measurements. The measurements were performed by
149   starting from the year 2017, looking back to previous years.
150
151   **Estimation of biomass and carbon content.**
152   In order to obtain the total aerial biomass, the equation developed by *Návar et al. (2004)* was
153   used for the species in question, which takes the basal diameter as a predictive variable (Equation
154   1).

$$y_i = a(DB)^b \qquad\qquad [1]$$

155   *Where*
156   y_i = *Total aerial biomass*
157   *a = 0.0199 y b = 2.5488*
158   *DB = Basal tree diameter (cm)*
159
160   The carbon content for *Pinus cooperi* was calculated according to the percentage reported by
161   *Pompa-García et al. (2017)*, who indicate that, the carbon concentration for this species is
162   49.64% of the total aerial biomass. For *Pinus durangensis* the carbon concentration reported for
163   Hernández-Vera *et al. (*2017) was used (50.36% of the total aerial biomass).
164   Considering that the terrain is relatively flat and homogeneous, an analysis of variance
165   (ANOVA) was performed under a completely randomized experimental design for the statistical
166   analysis of the data. The classification variables were the two studied tree species and the tree
167   age. The response variables were the year-by-year width of the tree ring, the biomass and the
168   carbon content. The Shapiro-Wilk Normality Test was used to evaluate data normality and
169   equality of variances for all response variables. Significant differences ($p \leq 0.05$) for the year-by-
170   year width of the tree rings were evaluated with the Tukey Means Comparison Test, while the
171   Kruskal-Wallis Non-Parametric Test was used to evaluate significant differences among the
172   median values of biomass and carbon content because these two variables did not meet the
173   normality data assumption. These analyzes were performed using R® statistical software *(R Core*
174   *Team, 2019)*.
175

Results

Table 1 shows the descriptive statistics of the sampled trees. Similarity is observed in the parameters evaluated (diameter at the base and total height), which means that, at the age of eight years, the studied tree species show similar growth patterns.

Table 1.

Eight years after the establishment of the plantation, an average survival of 75.2% was observed for the two species, which corresponds to a density of 1,881 trees per ha (Table 2). From studied sites stand out 10 and 2 which showed the highest and lowest survival rates, respectively. No survival comparisons were made, because it was not possible to know the proportion in which both species were planted, however, *Pinus durangensis* was found to be planted in a greater quantity (almost double according to the observed average of the number of trees of the sampling sites), and assuming that survival had been the same for the two studied trees species, an initial density of 2,500 trees ha^{-1} was planted (25 trees in 1000 m^2).

Table 2.

The analysis of variance indicated that there are highly significant statistical differences (*p <0.001*) in the year-by-year width of the tree rings of the studied tree species. The Tukey test (Fig. 2), forms 6 groups for both tree species, among these, the values of the first and fifth year stand out, which were, respectively, the minor and major width rings. Starting from fifth year, the width of the tree rings shows a decline, and allows their values to be grouped with the values of the third and fourth years. Although the width of the tree rings was slightly larger in *P. cooperi*, no significant statistical differences (*p = 0.9336*) were found among the two studied tree species. The upper and lower horizontal lines crossing the vertical bars (standard deviation) indicate that the year-by-year width growth of the tree rings has been similar among the tree species until the period of time evaluated in this study.

Figure 2.

The Kruskal-Wallis Test indicated that there are significant differences in the estimates of year-by-year biomass and carbon content (*p ≤ 0.05*). The comparison of medians using the Bonferroni method does not show significant differences in those years whose observations were consecutive. In contrast, comparisons between discontinuous years showed significant differences (*p <0.01*) (Table 3).

Table 3.

Estimates of year-by-year biomass and carbon content among tree species did not show significant statistical differences (*p ≥ 0.05*).
The accumulation of biomass showed higher values after the fifth year in the studied species, which is a product of the increase in the dimensions of the BD of the trees (Fig. 3).

Figure 3.

222 Estimates of biomass and carbon content year-by-year of the studied species are shown in Table
223 4. It is observed that the accumulation of biomass and carbon content increases with increasing
224 age. However, *Pinus cooperi* shows a decrease in the seventh year with respect to the previous
225 year. Considering that a tree has in average an estimate of 4.42 and 2.21 kg of biomass and
226 carbon content, respectively, at the age of 7 years, the studied plantation accounts for 8,315.12
227 and 4,157.56 kg ha^{-1} of aerial biomass and carbon, respectively.
228
229 **Table 4.**
230
231 **Discussion**
232 The results of survival reported in this work (75.2%) are superior than the findings reported by
233 *Prieto et al. (2016)*, who found out an average of 43% in a forest plantation studied in Durango
234 State. These survival results are also superior to those showed by *Bojórquez, Rodríguez & Flores*
235 *(2015)* in 25-year-old plantations of *P. durangensis*, *P. engelmannii*, *P. cooperi* and *P. arizonica*
236 var. in Durango State. Although different species were dealt with in a similar study, our results
237 are also better than those reported by *Vásquez-García et al. (2016)*, who informed an average
238 survival of 69% in four-year old plantations of *P. greggii* Englem and *P. oaxacana* Mirov - in
239 three communities in the High Oaxacan Mixtec region in Southern Mexico. However, our
240 survival results were inferior than those reported by *Prieto-Ruiz et al. (2007)* in an 18-month
241 *Pinus cooperi* plantation established on a site in the municipality of Durango, reaching a survival
242 rate of 85.6%. They are also inferior than those informed by Prieto-Ruiz et al. (2018), who
243 reported a 93% of survival in a *Pinus cooperi* plantation after 13 months of its establishment at a
244 site in Agua Zarca, Otinapa, Durango.
245 *Prieto et al. (2018)*, argue that successful plantations and reforestations depend on the quality of
246 the plant, as it is decisive for its adaptation and development after planting *(Fontana, Pérez &*
247 *Luna, 2018)*. In our study, it is observed that both species show uniform growth from their
248 establishment to the fifth year of planting. However, from the sixth year onwards, plant growth
249 tends to decline, remaining low until the end of the study, being more noticeable in *P. cooperi*.
250 *Crecente-Campo et al. (2007)* documented that the decrease in plant growth is influenced among
251 other factor by the competition that trees experience from other trees, and that competition
252 increases with increasing age of the plantation *(Soto-Cervantes et al., 2016)*.
253 Although this work does not include an analysis that correlates ecological factors with tree
254 growth, studies performed by *Anchukaitis et al. (2013), Gutiérrez-García & Ricker (2019),*
255 documented that maximum temperature negatively influences radial growth of the trees.
256 However, the growth, and consequently, the CO_2 sequestration may vary with environmental
257 conditions of the site and the tree species evaluated *(Haghshenas et al., 2016; Pompa-García &*
258 *Sígala-Rodríguez, 2017; Lanza, Chartier & Marcora, 2018)*. These growth patterns can be
259 attributed to the fact that, at the beginning of the plantation, the genotype-environment
260 interaction and the plasticity of the species influence the adaptability of the plants to a specific
261 sites *(Miranda, 2006; Thomas et al., 2015)*.
262 The width of the tree rings is the most used parameter to evaluate the growth rate of the trees
263 *(Dobner, Huss & Tomazello, 2018)*. In this study, the lowest width ring growth value was
264 presented during the first year, this can be attributed to plant adaptation to transplant stress (e.g.,
265 drought, salinity, and temperature extremes) *(Pérez-Luna et al., 2020)*. On the other hand, the
266 tree development during the fifth year was higher and after that it showed some reduction in
267 growth caused by tree competition *(Crecente-Campo et al., 2007)*. The average width growth of

268   the rings observed for both tree species was 11.51 mm yr^{-1}. *Pompa-García et al. (2018),*
269   evaluated the width growth rings in *P. arizonica* y *P. cembroides* Zucc in northern Mexico and
270   found that their average increase was 1.84 mm yr^{-1} and 1.73 mm yr^{-1}, respectively.
271   A study in *Pinus taeda* L. developed by *Dobner, Huss & Tomazello (2018)*, found out that the
272   width growth of tree rings varied between 6 to 9 mm during the first three to six years before
273   performing silvicultural activities. On the other hand, *Melandri, Dezzeo & Espinoza de Pernía*
274   *(2007)* in a study with *Pinus caribaea* var. hondurensis in Venezuela indicated that the width
275   growth of tree rings is dependent on various site factors, as well as atmospheric, in this case they
276   pointed out that different rainfall regimes yielded significantly differences in with growth rings.
277   Several studies related the radial growth rate and the characteristics of the rings with
278   environmental variables such as temperature, precipitation and light intensity *(García-Suárez,*
279   *Butler & Baillie, 2009; Chacón-de la Cruz & Pompa-García, 2015).* However, due to the
280   dynamics of the exchange activity during the formation of the wood, the relationship of growth
281   with climatic conditions is very complex and inconstant *(Żywiec et al., 2017).*
282   Studies indicate that tree spacing influences total tree volume, width growth of rings, and length
283   and diameter of branches *(Hart, 2010).* Also, with increasing thinning intensity the effect on the
284   thickness of the width of tree rings is greater *(Zhang et al., 2006). Baldwin et al. (2000)*, studied
285   the effects of spacing and thinning on stand and tree characteristics of a 38-year-old *Pinus taeda*
286   L plantation and found out that, at higher initial spacing, trees develop greater diameter and
287   crown length. This favors the formation of wider tree rings and more early wood *(Rossi, Morin*
288   *& Deslauriers, 2012). Rodríguez-Ortiz (2010),* recommended an initial spacing of 2.40 to 2.75 m
289   for *Pinus patula* Schl, because it is a tree species sensitive to competition during its first years of
290   development.
291   In this study, estimates of year-by-year biomass and carbon content were analyzed for individual
292   trees, however, estimates per hectare were not performed because survival in previous years was
293   unknown and results extrapolation based on survival at the time of assessment could be
294   considered erroneous. In this study the average carbon content per tree was estimated in 0.30 kg
295   yr^{-1} for both studied tree species. *Pompa-García et al. (2018)* estimated that adult trees of *Pinus*
296   *arizonica* and *P. cembroides* accumulate 4.80 kg C yr^{-1} and 4.84 kg C yr^{-1}, respectively. *Pacheco*
297   *et al. (2007)* evaluated the accumulated biomass content in a six-year-old *Pinus greggii*
298   plantation, and found out that the average aerial dry biomass was 8.0 kg per tree. These results
299   are above those observed in this study with an average per tree of 4.39 kg for *Pinus durangensis*
300   and 4.46 kg for *P. cooperi*.
301   Intensive forestry is key to maintaining or increasing stand productivity in the future, wood
302   biomass from plantations of fast-growing trees is an alternative because it is produced in short
303   periods of time *(Thiers, Gerdinga & Schlatter, 2007).* However, intensive forest management
304   may impact the conservation of plant diversity and the regulation of water flows *(Monárrez-*
305   *González et al., 2018).* The results of this research suggest that clear-cuttings are suitable logging
306   practices for the studied tree species in the study area, especially because they create optimal
307   growing conditions for pine trees. However, after opening the gaps it is recommended to replant
308   the area with certain additional complementary practices to protect and guarantee its good
309   development (e.g. fencing, firebreaks, pest prevention, etc.), and avoid risk of soil erosion and
310   loss of biodiversity. The estimates of carbon content made in this study coincide with the results
311   reported by *Pacheco et al. (2007)*, in the sense that young plantations have high growth rates and
312   therefore they also have a greater potential for carbon sequestration.
313

Conclusions

According to the results of the present study, the observed survival percentage (75.2 %) is considered high in comparison with other similar studies. It indicates that both *Pinus durangensis* and *P. cooperi* adapt and develop well in areas harvested with clear-cutting in the forests of Durango. The width growth of the tree rings was similar in the two species but different among the years evaluated. No significant differences were found in terms of biomass and carbon content among the studied tree species. The accumulation of biomass and carbon content observed in the studied forest plantation is considered to be high, accounting for 8,315.12 and 4,157.56 kg ha^{-1}, respectively, at the age of 7 years. The study reveals that clear-cuttings can be successfully used as logging practices in the study area to create even aged pine stands and increase the productivity of these forests in terms of timber and CO_2 sequestration, among other ecosystems services.

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Figure 1

Study area, showing the locations of the sampling sites used in the analysis.

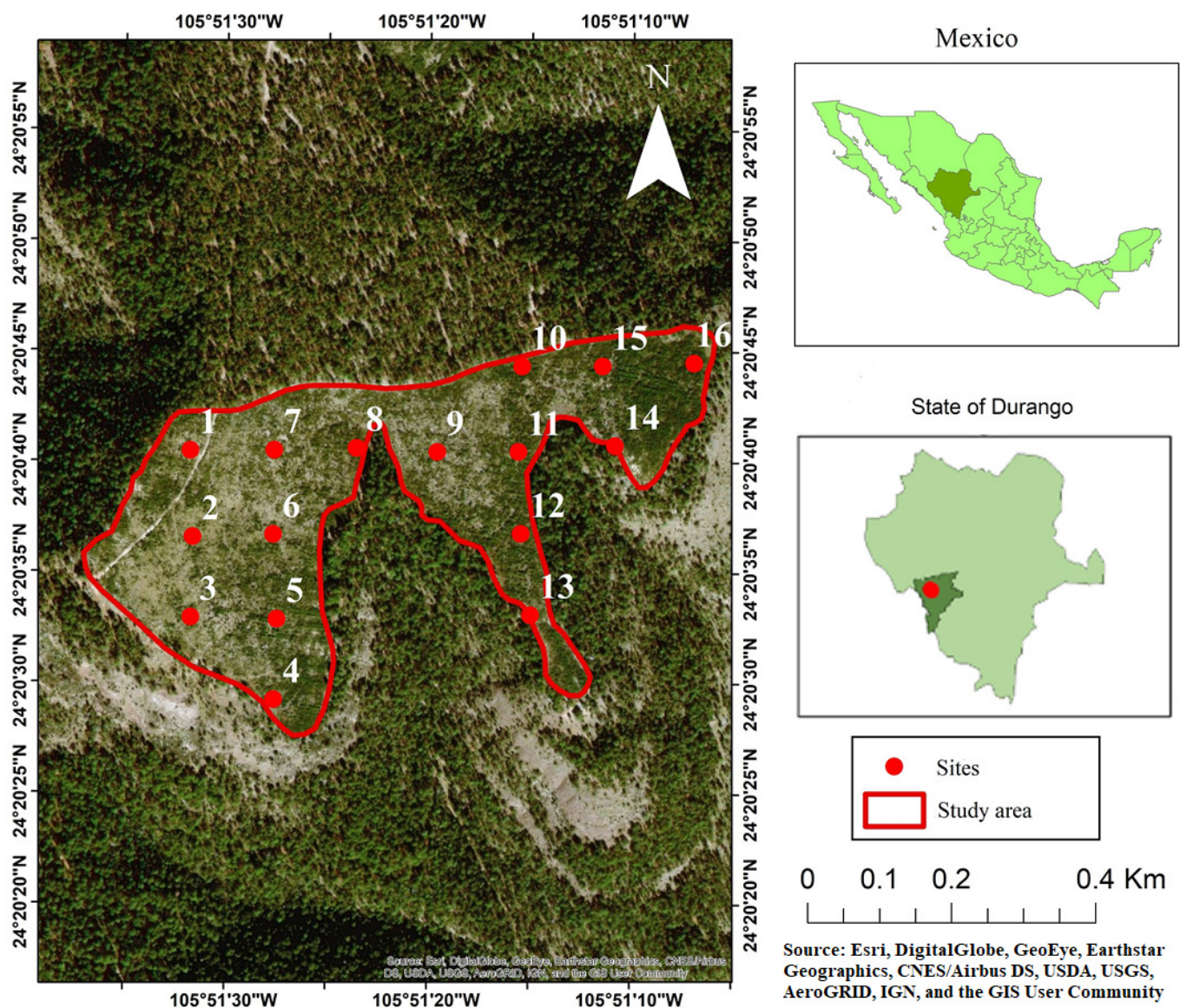



Figure 2

Average values (bars), standard deviation (lines) and groups of means according to Tukey (letters) of the ring width by species and year.

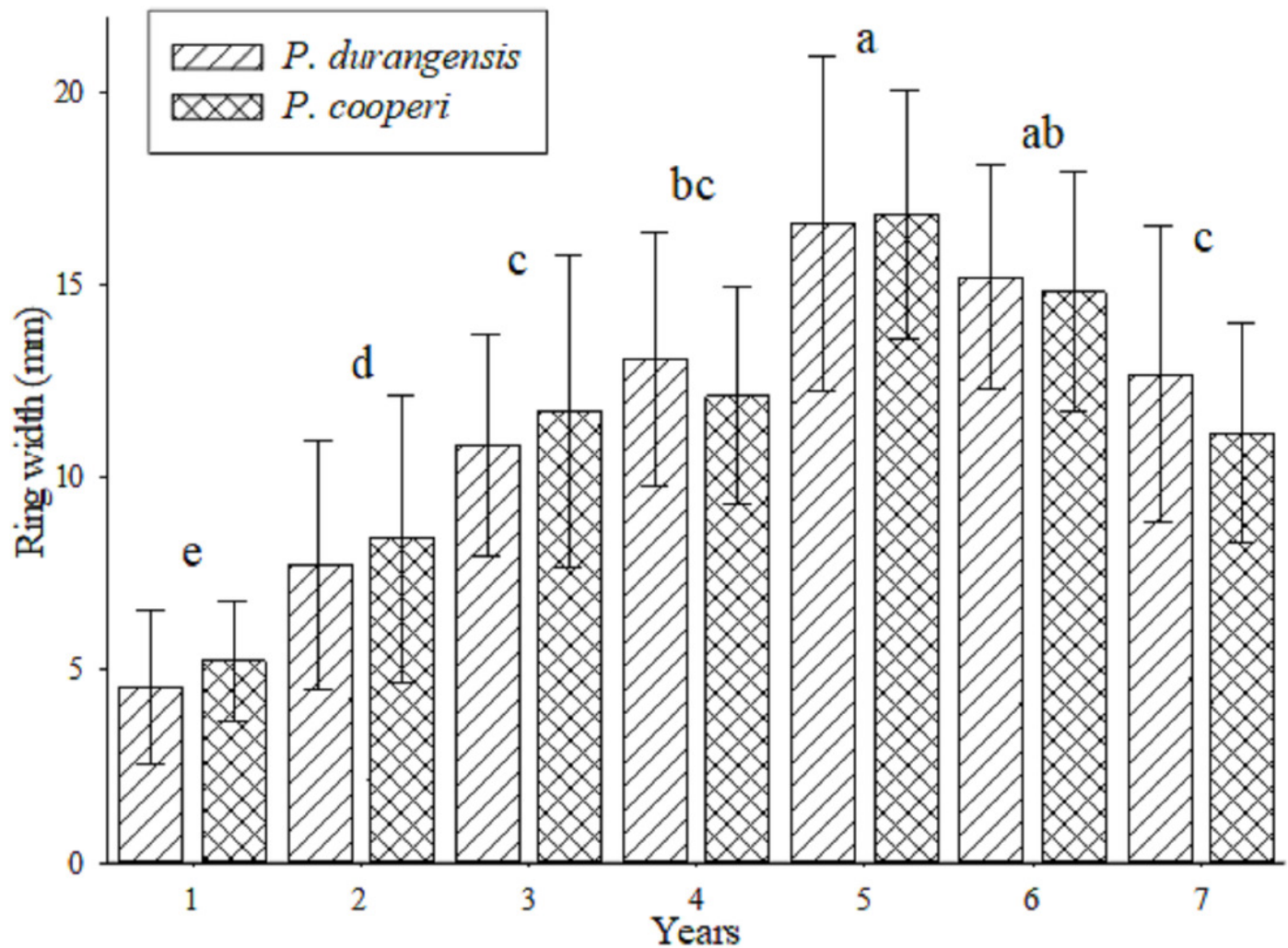
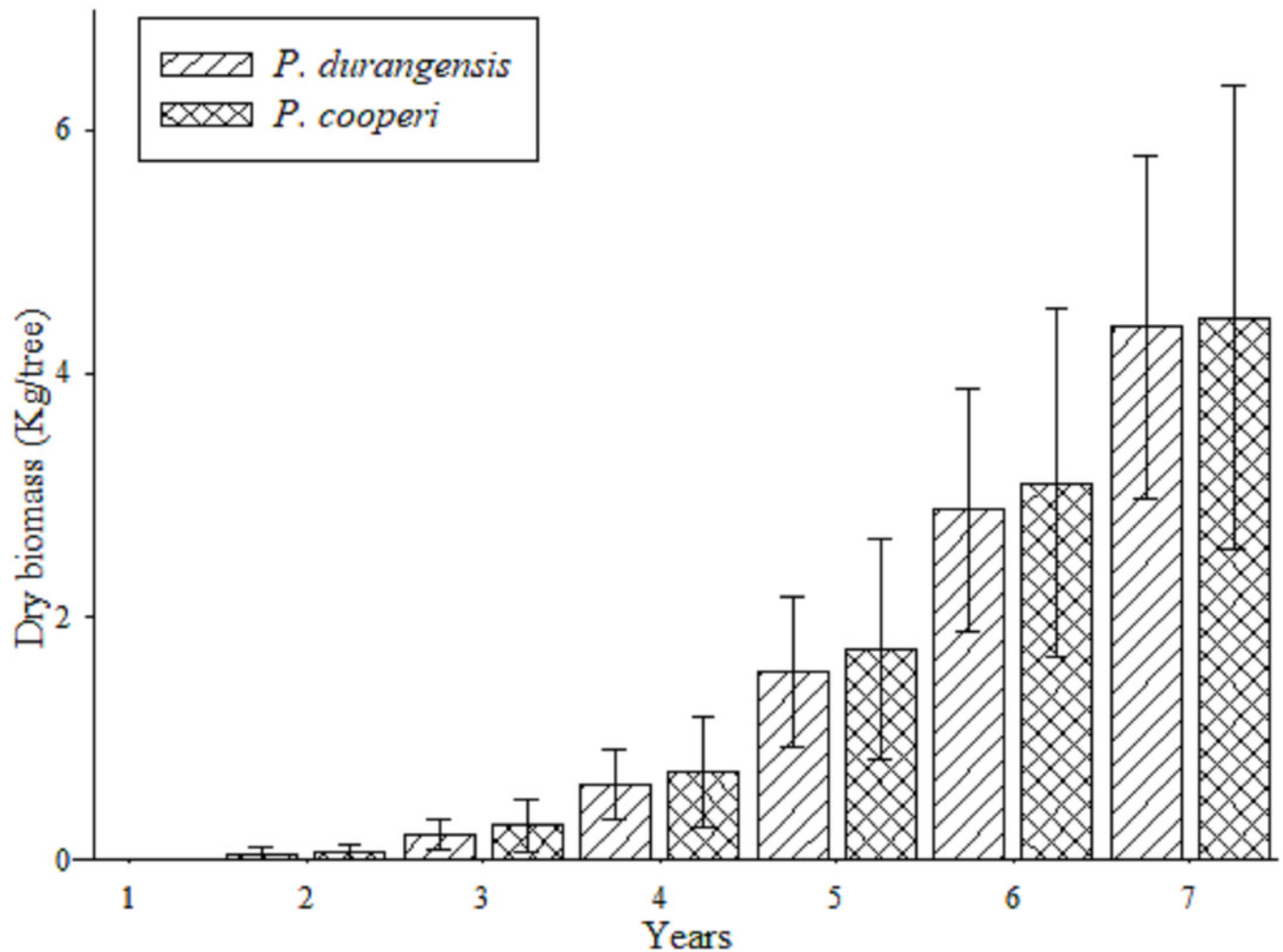



Figure 3

Average values and standard deviation of the total accumulated aerial biomass by tree of *P. durangensis* and *P. cooperi.*

Descriptive statistics for the diameter at the tree base and height of the sampled trees of *Pinus durangensis* and *P. cooperi* that were analyzed in this study (eight years old).

DB = basal diameter, M = Mean, Var = Variance, Std = Standard deviation, C.V. = Coefficient of Variation

1 **Table 1.** Descriptive statistics for the diameter at the tree base and height of the sampled trees of
2 *Pinus durangensis* and *P. cooperi* that were analyzed in this study (eight years old).

Species	Trees	DB (cm)				Height (m)			
		M	Var.	Std	C.V.	M	Var	Std	C.V.
P. durangensis	16	8.21	1.13	1.06	0.13	3.47	0.33	0.58	0.17
P. cooperi	16	8.17	2.24	1.5	0.18	3.3	0.67	0.82	0.25

3 DB = basal diameter, M = Mean, Var = Variance, Std = Standard deviation, C.V. = Coefficient of Variation

Number of trees observed by site and tree species.

n = number of trees recorded in site i, N= Number of trees per hectare, %= Percentage of survival.

1 **Table 2.** Number of trees observed by site and tree species.

Site	n	N	%	Pinus durangensis		P. cooperi	
				n	%	n	%
1	19	1,900	76	14	56	5	20
2	10	1,000	40	7	28	3	12
3	18	1,800	72	11	44	7	28
4	20	2,000	80	12	48	8	32
5	15	1,500	60	7	28	8	32
6	18	1,800	72	13	52	5	20
7	19	1,900	76	13	52	6	24
8	21	2,100	84	12	48	9	36
9	20	2,000	80	8	32	12	48
10	24	2,400	96	13	52	11	44
11	23	2,300	92	16	64	7	28
12	23	2,300	92	21	84	2	8
13	18	1,800	72	12	48	6	24
14	11	1,100	44	8	32	3	12
15	23	2,300	92	18	72	5	20
16	19	1,900	76	15	60	4	16
Mean	18.81	1,881.25	75.20	12.5	50	6.31	25.25

2 n = number of trees recorded in site i, N= Number of trees per hectare, %= Percentage of survival.

Pairwise comparisons of the estimation of year-by-year biomass and carbon content according to the Bonferroni medians comparison test.

* a significant difference at *p < 0.05*, ** a significant difference at *p < 0.01*, *** a significant difference at *p < 0.001*.

1 **Table 3.** Pairwise comparisons of the estimation of year-by-year biomass and carbon content
2 according to the Bonferroni medians comparison test.

Comparison (year)	Biomass	Carbon
1 vs 2	0.9507	0.9508
1 vs 3	0.0013**	0.0014 **
2 vs 3	0.9816	0.9907
1 vs 4	<0.0001***	<0.0001***
2 vs 4	0.0034**	0.0035**
3 vs 4	1	1
1 vs 5	<0.0001***	<0.0001***
2 vs 5	<0.0001***	<0.0001***
3 vs 5	<0.0001***	<0.0001***
4 vs 5	0.1064	0.1065
1 vs 6	<0.0001***	<0.0001***
2 vs 6	<0.0001***	<0.0001***
3 vs 6	<0.0001***	<0.0001***
4 vs 6	<0.0001***	<0.0001***
5 vs 6	1	1
1 vs 7	<0.0001***	<0.0001***
2 vs 7	<0.0001***	<0.0001***
3 vs 7	<0.0001***	<0.0001***
4 vs 7	<0.0001***	<0.0001***
5 vs 7	1	1
6 vs 7	1	1

3 * a significant difference at $p < 0.05$, ** a significant difference at $p < 0.01$, *** a significant difference at $p < 0.001$.

Year-by-year biomass and carbon content for the studied pine tree species planted in a site after being harvested with a clear-cutting.

Std= Standard deviation

1   **Table 4.** Year-by-year biomass and carbon content for the studied pine tree species planted in a
2   site after being harvested with a clear-cutting.

Age (year)	Biomass *P. durangensis* (kg Tree⁻¹)		Biomass *P. cooperi* (kg Tree⁻¹)		Carbon *P. durangensis* (kg Tree⁻¹)		Carbon *P. cooperi* (kg Tree⁻¹)	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	0.006	0.005	0.008	0.005	0.003	0.003	0.004	0.002
2	0.047	0.045	0.060	0.049	0.024	0.023	0.030	0.024
3	0.164	0.086	0.223	0.166	0.082	0.043	0.111	0.083
4	0.404	0.183	0.429	0.250	0.203	0.092	0.213	0.124
5	0.934	0.397	1.014	0.470	0.470	0.200	0.503	0.233
6	1.324	0.451	1.366	0.583	0.667	0.227	0.678	0.290
7	1.509	0.608	1.362	0.559	0.760	0.306	0.676	0.278
Total	4.388	1.776	4.461	2.083	2.210	0.894	2.215	1.034

3   Std= Standard deviation