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Provenance trials of the Mexican spruces in nursery conditions: Three species endangered by climatic variation

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Abstract: The three Mexican spruces' distributions are fragmented, which could lead to phenological, morphological and genetic differentiations, partially caused by local adaptation. In this study we examined the effect that climatic variables have on the survival and growth of 5,641 *Picea* seedlings, coming from eight seed provenances and produced in identical nursery conditions. The respective responses of each species and provenance can be considered as a proxy of the genetic differentiation and adaptation of each population. A cluster analysis revealed: i) significant differences in the genetic quantitative traits among the three *Picea* species and ii) significant correlations among genetic quantitative traits and climatic factors.

Keys words: Provenances and progenies trial; Adaptation.

1. Introduction

In Mexico there are three endemic species of the *Picea* genus, which live in relict populations and they are listed as "Endangered" in the Red List of the IUCN [1]. *P. mexicana* has only three locations, above 3,000 m elevation [2,3], *P. martinezii* is in four populations between 1,800 and 2,500 m [4] and *P. chihuahuana* has been found in 40 sites between 2,311 and 2,700 m of altitude [2,5]. The Mexican spruces' distributions are fragmented in isolated populations, which could lead to phenological, morphological and genetic differentiations, partially caused by local adaptation to different soil types and climatic variables [6]. Therefore, it is important to identify the main factors responsible for such adaptation, which could be helpful in assisted migration programs as an option for ex-situ conservation. Provenance-progeny trials allow the design of conservation programs for saving genetic resources in the medium and long terms. In our experiment we studied the genetic and environmental components of the phenotypical variation among trees of different provenances [7]. In fact, we examined the effect that climatic variables have on the survival and growth of seedlings of each *Picea* species' provenances, in equal nursery conditions, assuming that such response could be a proxy of the adaptation or the genetic differentiation among populations.

2. Experimental Section

We based our study on eight provenances of the three Mexican spruces, located in four states of Mexico: one provenance is from Chihuahua, one from Durango, one from Coahuila and five from Nuevo Leon. The mean 100-seed weight based on three trees per provenance was measured with a digital weight balance (Velab model No. VE-5000H, Mexico). We established our provenances trial experiment in a nursery at El Salto, municipality of Pueblo Nuevo, Durango, in an elevation of 2,590 m, where each seedling was put in one round container of 165 cm^3. There, we measured the survival of 5,641 seedlings and their growth in diameter (mm) and height (mm), during 12 months. All these seedlings grew in the same climate and soil conditions. On the other hand, values of 22 bioclimatic variables were modeled for each provenance [8].

We used the Spearman´s correlation (rs) test [9] to look for potential relationships between mean growth (Diameter x Height, mm^2), 100-seeds weight and each analyzed climatic variable from each species and provenance. We used the same test to detect collinearity between climatic variables. The mean growth differences among the three species were tested with the Tukey and Kramer (Nemenyi) test, defining the Tukey-distribution using the PMCMR package of the statistical program R [10]. We also applied a Bonferroni correction, with an original $\alpha = 0.05$ and a corrected $\alpha = 0.002$.

3. Results

The Nemenyi test indicated significant differences in Diameter x Height between the three spruces (Table 1.)

Table 1. Absolute growth and growth differences of seedling Diameter x Height (mm) from *Picea chihuahuana*, *P. mexicana y P. martinezii* and their *p* values tested by Tukey and Kramer (Nemenyi) test with Tukey-distribution.

Species	Means of growth (Diameter x Height) (mm)	Absolute differences among the three Mexican spruces (*p* value)	
		Picea martinezii	*Picea mexicana*
Picea chihuahuana	461	765 (2.8e-14)	367 (1.3e-07)
P. mexicana	828	398 (< 2e-16)	
P. martinezii	1,226		

After the Bonferroni correction, we detected significant correlations between the seedling's genetic proxy (Diameter x Height) and some climatic variables (Table 2 and Figure 1). We did not find any significant correlation between the mean 100-seed weight and mean growth of the seedlings ($r_s = 0.69$, $p = 0.069$).

Table 2. Significant Spearman's correlations (rs) found between growth (Diameter x Height) and some climatic variables; Mmin = Mean minimum temperature in the coldest month (Celsius degrees), Smrsprpb = Summer/Spring precipitation balance: (jul+aug)/(apr+may).

Variable	Units	r_s	*p* value
Smrsprpb	mm	-0.97	0.00007
Mmin	°C	0.90	0.00244

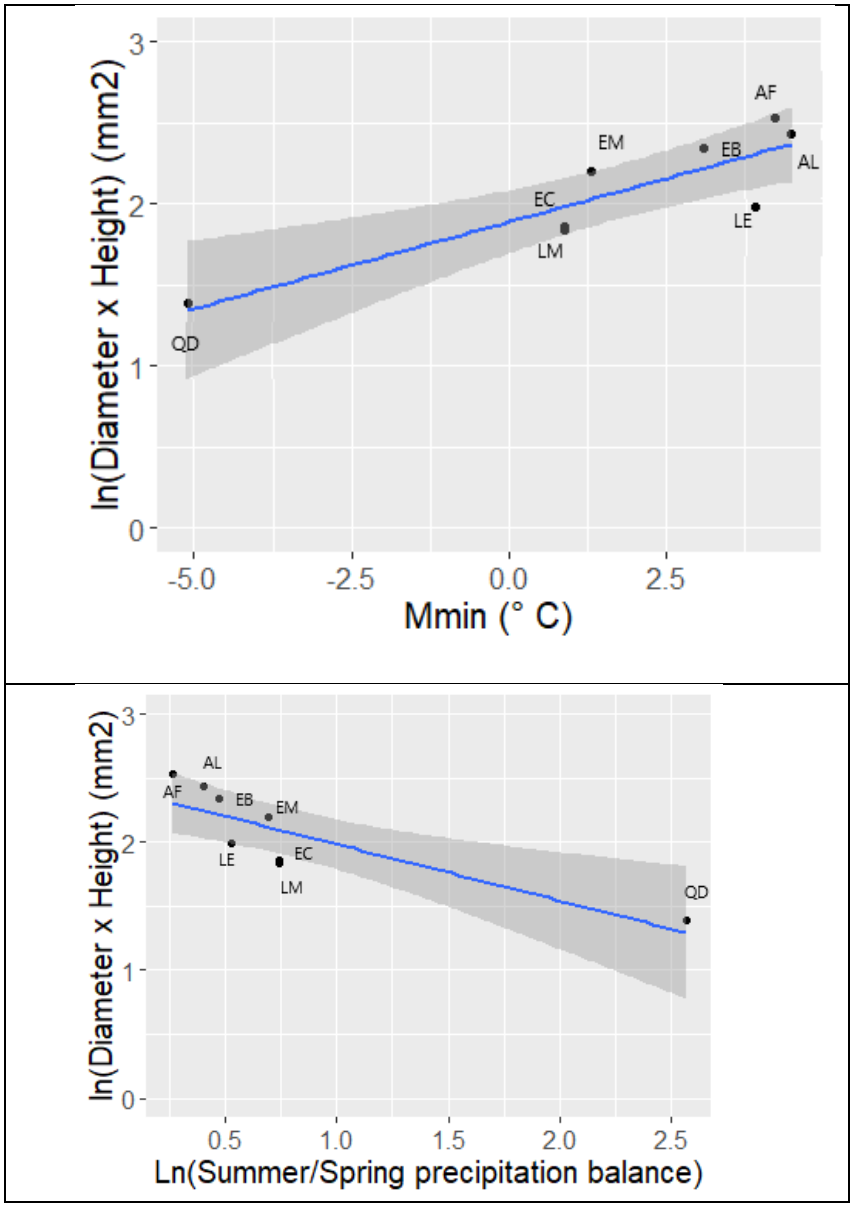

Figure 1. Spearman´s correlations between growth (Diameter x Height) of the seedlings and the two most significant climatic variables: Mmin = Mean minimum temperature in the coldest month (centigrade degrees) and Smrsprpb = Summer/Spring precipitation balance: (jul+aug)/(apr+may); *Picea martinezii*: Locations AF= Agua Fria, AL= Agua Alardin, EB= El Butano and LE= La Encantada, *Picea mexicana*: Locations EM= El Mohinora, LM= La Marta and EC= El Cohuilon and *Picea chihuahuana*: Location QD= Quebrada de los Duran.

4. Discussion

Our results suggest that there are significant quantitative genetic differences among the three analyzed *Picea* species and that these differences are correlated with two climate variables (the mean minimum temperature in the coldest month and the Summer/Spring precipitation balance), supporting the adaptation hypothesis to local conditions [6]. In another study, it was reported that the precipitation was a moderately good predictor of height growth in *Picea mariana* [11], while Castellanos-Acuna et al. [12] found that the mean coldest month temperature (MCMT) and an aridity index (AHM) are strongly related to the genetic adaptation of tree species.

5. Conclusions

Our findings about different effects of climatic variables on the three studied endangered *Picea* species and their provenances may have important practical implications for *ex-situ* conservation strategies. Besides, reforestation programs should be more successful if the seedlings of a given species are planted in very similar climatic conditions to the ones of its provenance, given the strong provenance-climate association [13].

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