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Effect of monthly precipitation on the radial growth of *Pseudotsuga menziesii* in northern Mexico

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In the context of global climate change, water availability is an essential factor for geographical distribution and abundance of plant species. *Pseudotsuga menziesii* has been reported as a highly sensitive species to climatic variation and is regarded as a genetic resource of invaluable importance. The objective of this paper was to evaluate the specific effect of precipitation on radial growth throughout year for this species. From historical climate records and tree ring cores collected in Mexican northern forests, growth was correlated with monthly precipitation by standard statistical techniques. Results showed that *P. menziesii* was more susceptible to winter precipitation prior to the growing season. Low precipitation in winter makes the survival of these individuals vulnerable. In light of our results, direct implications for management strategies of *P. menziesi*, are discussed.

Key words: Radial growth, tree-rings, dendrochronology, tree growth–climate relationships.

INTRODUCTION

Interest in studying the influence of climate to predict the distribution and abundance of plant species has grown considerably (Yen and Wensel, 2000; Manthey and Box, 2007). In the context of global climate change, the possibilities for study offered by the rings of conifers are exceptional because they are permanent, periodic, and continuous records. This means that data may be available for extended periods, as well as for species lifespan (Stahle et al., 2011). Diameter annual growth makes possible to establish a chronological correspondence of age with natural variables along time periods e.g. climate variables. Several authors report that the causes of these behaviours are climatic variations on which the dynamics of growth depend (Manrique and Fernández, 1999; Cerano et al., 2010).

The effect of climatic variables in natural systems is usually modelled at regional scales by functional groups of vegetation (Retuerto and Carballeira, 2004). However, the consideration of climatic parameters will produce changes not only at the ecosystem level, but also of the species *in situ* (Gómez et al, 2008). This implies that variation of physiological mechanisms within and among species allows the identification of their climatic tolerance (Laurent and Vilá, 2003).

Several studies have reported that *P. menziesii* is one of the most sensitive species to climatic variations with emphasis on precipitation (Villanueva-Díaz et al*.,* 2009; Cerano et al*.,* 2011). According to Seager et al. (2009),

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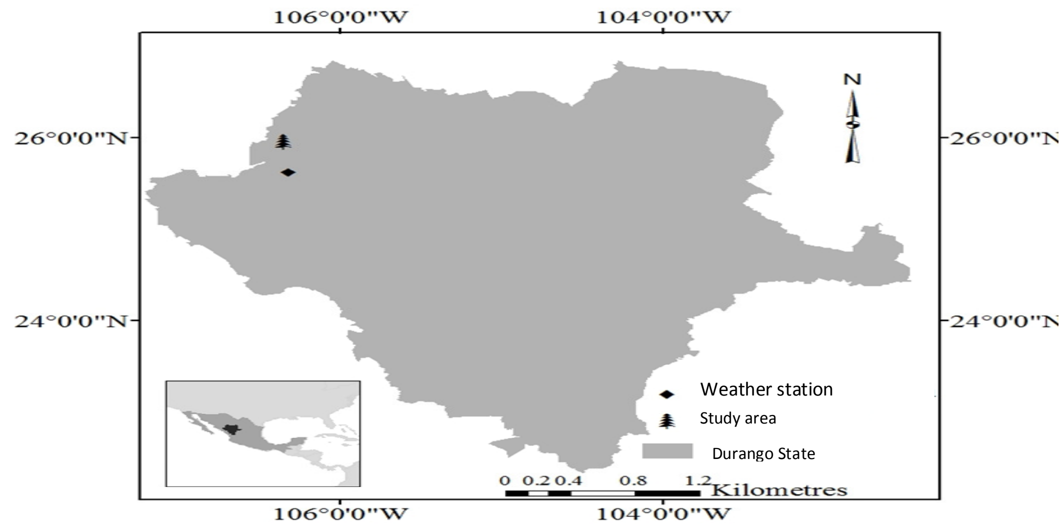

Figure 1. Location of the study area.

global warming has led to a drought in the ecosystems of the northern region of Mexico. Moreover, Durango state forests have become critical from a hydrological point of view. They have a direct impact on the regional economy because they supply water for large cities and vast agricultural areas (Cleaveland et al., 2003), so the species' response to water availability is of particular importance. Besides, analyzing the hydroclimatic effect at species level remains poorly understood. Its current tolerance can be compared with future scenarios to evaluate its vulnerability to changes in precipitation. Therefore, the aim of this study was to evaluate the specific sensitivity of monthly precipitation on the radial growth of *P. menziesii*.

METHODS

Description of the study area

The study sites were located in the Ejido "El Cócono", Guanaceví municipality, Durango state (25.549° N, 106.324° W; 1950m) (Figure 1). The vegetation of the site corresponded to a mixed forest with a dominant tree layer of *Pinus duranguensis* (Martinez), *P. arizonica* (Engelmann), *P. ayacahuite* (Ehrenb), *P. menziesii* (Mirb.) Franco, fir (*Abies durangensis* Martinez), strawberry tree (*Arbutus xalepensis*) and several species of oak (*Quercus* spp). In the understory, a presence of a variety of shrub and herbaceous species is seen (González et al., 2007). Climate is Cb '(w2)x' type (Pompa et al., 2012).

Data

Sites located in different bioclimatic belts were selected, looking for representative trees. From at least ten trees selected, two or three ring cores were taken with the support of increment borers of different dimensions (Haglof, Sweden). Likewise, cross-sections were obtained using a chainsaw from stumps, dead trees or wood partially buried in the forest floor. Sites were characterized in poor-quality conditions all with the same slope and exposure to reduce their effect on growth. We avoided injured or deformed trees, as well as those whose growth may have been influenced by competition for light or soil nutrients. In order to serve as comparison to sampled trees and make easier dating of cores, rings from tree-stumps and young trees were collected.

Samples were processed using standard dendrochronological techniques. Dating and measurement accuracies of growth ring were estimated using the program COFECHA, which is part of dendrochronological programs known as the Dendrochronology Program Library (Stokes and Smiley, 1968; Holmes, 1983). Biological and geometric trends not related to climate effect were removed by the ARSTAN program (Cook and Holmes, 1984). A cubic smoothing spline was fitted to the ring-width series and then dividing each annual value of measurement between the value obtained from the curve; the standard index series with mean 1.0 and variance 0 were generated (Cook, 1987).

In order to facilitate the study of correlation between tree growth and average monthly precipitation (mm), sampling sites were located as close as possible to the area of influence of the weather station in the locality of Tarahumar, municipality of Tepehuanes, State of Durango (25° 37'12'' N and 106° 19'12'' W; 2435 masl) with records from 1922 to 1987. Most rainfall occurred during the summer period, when 76% of the total annual precipitation was accumulated, and the rest (24%) was recorded during the winter (Figure 2).

To determine the degree of influence of precipitation on the growth of the species, the ring-width index (RWI) was correlated with the monthly climate data of the study period, using the Pearson coefficient through the statistical software SAS/STAT® (SAS Institute Inc., 2004). Its expression is:

$$\rho_{xy} = \frac{Cov(x, y)}{\sigma_x \cdot \sigma_y}$$

Where ρ_{xy} is the correlation, $Cov(x, y)$ is the covariance, and σ_x, σ_y are the standard deviations between two random variables *x* and *y*, respectively (RWI and precipitation, in this case). Furthermore, the results of the monthly correlations were plotted

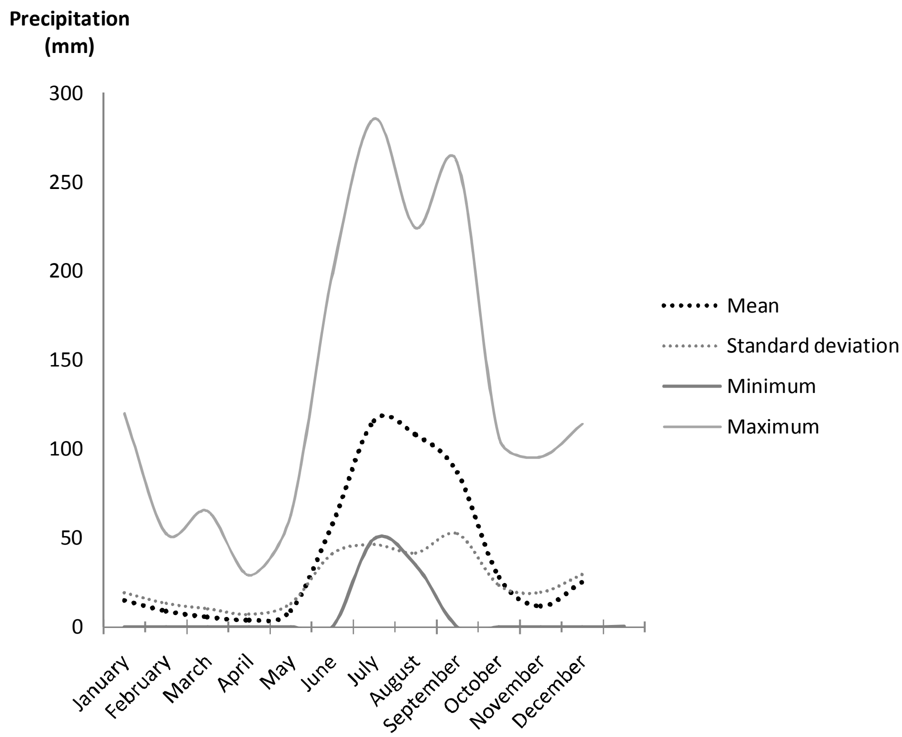

Figure 2. Historical monthly precipitation from 1922 to 1987 for weather station in the locality of Tarahumar, Tepehuanes municipality, Durango (25°17'30'' N, 106°39'5'' W).

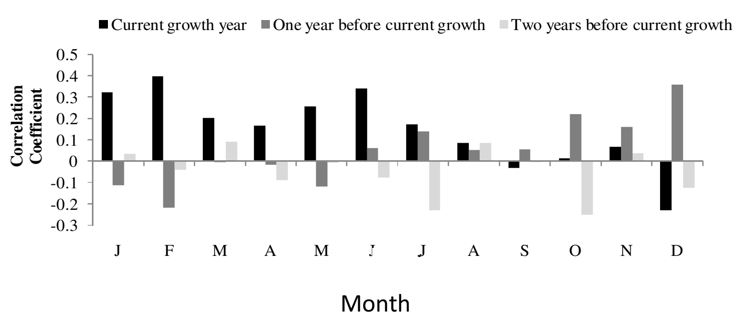

Figure 3. Correlation of monthly precipitation with the ring-width index of *P. menziesii* from 1992 to 1987.

graphically with the index of a standard ring to detect whether the growth of previous years had an influence on the current year (Fritts, 1976). Furthermore multiple regressions between RWI and monthly precipitation were conducted. The multiple regression variables were selected from those climatic variables significantly correlated with RWI. A stepwise regression was then carried out with a level of significance at 0.10 for a variable to enter into the final model. This method looks at all the variables already included in the model and deletes any variable that does not produce an *F* statistic at the required level of significance (SAS, 2004).

RESULTS AND DISCUSSION

The Pearson´s coefficients (significance at the 0.05 level) described that precipitation were held in positive which was common in current January, February, March, April, May, Jun, and July, whereas current December showed negative values. The patterns of 1 year before current growth were positive in previous October, November and December. In contrast, an inconsistent pattern was observed for 2 years before current growth. The strongest correlations were found in previous December and current January and February (Figure 3). This shows that tree growth is regulated by the initial conditions of the year of growth and the final conditions of the previous year, but not with 2 years before the growing season. The positive coefficients account for a direct relationship

Table 1. Model for RWI and monthly precipitation selected by stepwise regression. Sub index denotes previous month of the year before current growth.

Variable	Parameter estimate	Standard error	Mean square error	R^2	Pr > F
Intercept	0.62407	0.05120			<.0001
March	0.00777	0.00220			0.00008
Jun	0.00193	0.00055	0.03291	0.6081	0.0008
Oct_{-1}	0.00328	0.00097			0.0013
Dic_{-1}	0.00497	0.00497			<.0001

-1 Denotes previous year growing season to the current-year one.

between the climate variable or previous growth with ring width; while a negative coefficient indicates an inverse relationship.

The Person´s coefficient analysis showed that the winter season was the most influential period on the growth of trees. Summer rains did not appear to significantly affect growth, even when they were abundant. Cerano et al. (2011) reports that cell division in the tree had already ceased during this period. They also suggested considering the soil infiltration capacity, because the amount of water often exceeds the soil infiltration capacity and causes runoff as overland flow. This observation is relevant, particularly in shallow soils that do not store much water during the growth phase.

Linear regression conducted between WRI against precipitation showed significant contributions to the models. Table 1 encompass those variables specific to different months. Precipitation was mainly related with current March and June and previous October and December. This results suggested correspondences with Figure 2. The stepwise regression explained 60% of the total variance. The highest parameter estimates obtained for previous month, indicated that winter precipitation had higher contribution in the model and also were significant. It is noteworthy that according to historical data, only one-third of the annual precipitation is recorded in the winter, while the rest occurs in the summer, revealing that more radial growth does not necessarily occur at higher precipitation levels. Winter rains are usually low-intensity, increase water infiltration and diminish evapotranspiration, producing a positive water balance (Constante et al., 2009). Another important aspect is when tree begins to grow in its vegetative period, usually in the spring, it has soil moisture availability. By other way, summer rains, are not fully available by trees because they have only 2 or 3 months to develop their growth before becoming dormant. The radial growth of *P. menziesii* was mainly influenced by winter precipitation. Table 1, and Figure 3 evidenced that water storage during tree dormancy period, is useful as reserve for next growing season. These studies are coincident with paleoclimatic ones developed in nearby regions (Díaz et al., 2002; Cleaveland et al., 2003; Villanueva-Díaz et al., 2007; Arreola and Návar, 2010). These similarities suggest that *P.*menziesil Growth is influenced by regional climate signals. Precipitation in previous winters was particularly important.

P. menziesii is a reliable species for dendrochronological studies (Cerano et al., 2010), showing good correlation between the growth index and the monthly precipitation. Statistical tests give evidence of the response that the species has to the availability of water over time. The correlation coefficient explained a satisfactory relationship between monthly precipitation and the growth index of *P. menziesii*, since Bogino et al. (2009) stated that these values rarely covered more than 60% of the variance. The species is sensitive to winter rain, as values of Pearson correlation coefficients of 0.36, 0.32, and 0.39 were detected for the months of December, January, and February, respectively, which was similar to previous studies in *Pinus sylvestris* L. (Bogino et al., 2009), *Abies alba* Mill. *Picea abies* Karst. (Lebourgeois, 2007), which showed high correlations of radial growth between individuals of different environmental conditions in France.

Although, there are many factors that influence the growth of the species in addition to their genetic potential, the importance of precipitation has been reported for *P. sylvestris* L., *P. nigra* Arnold, and *P. pinea* L. (Campelo et al., 2006; Andreu et al., 2007), as well as for Northern California conifers. These studies conclude that precipitation has a high association with the growth of the species (Yen and Wensel, 2000; Bogino and Bravo, 2008). That is, the radial growth of *P. menziessi* is strongly associated with the availability of water in winter, which means it is an indicator species that can be used to reconstruct historical conditions of precipitation in forest. This finding supports the hypothesis that wet winters contributed to photosynthesis and, therefore to tree growth (Chen et al., 2010). Winter precipitation increases water stored in soil, which finally surpasses critical levels required to break bud dormancy and hence start tree growth. In addition, its study is especially useful for the analysis of temporary fluctuations in precipitation, as well as for the evaluation of global changes of climate effect on the growth of trees.Sensivity modeling of radial growth of *P. menziesii* to precipitation contributes to the knowledge on adaptation and response of vegetation to climate change at a species level. The results of this study can help define strategies for the protection and management of the species based on water availability. For instance, the reforestation season should be done in winter season, rather in summer as is usually practiced. Higher water availability will likely result in growth beginning several weeks earlier in the spring than at summer, allowing forests to take advantage of increased winter precipitation for early growth. Thus, *P. menziesii* will be less vulnerable to drought stress. Positive relationships between growth and previous winter rainfall support these inferences. Although the current drought has not been as critical as that of 1950 reported by Villanueva-Diaz et al. (2007), these results may have impact on the region socially and economically. The main agricultural activities in the area require an intensive use of water, which when added to its indiscriminate use, affects water availability in these ecosystems (CNA, 2006).

Conclusion

The radial growth of *P. menziesii* showed a statistically significant sensitivity to winter precipitation, rather than the summer rainfall. The rain in the winter before the growing season is a decisive factor in the development of the species. In fact, it has implications for the management regimes of this species. A drastically dry winter will make the permanence of these individuals vulnerable to pests and diseases.

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REFERENCES

Andreu L, Gutiérrez E, Macias M, Ribas M, Bosch O, Camarero J (2007). Climate increases regional tree-growth variability in Iberian pine forest. Glob. Chang. Biol. 13:804-815.

Arreola OMA, Návar Ch. JJ (2010). Analysis of drought and biomass productivity with Pseudotsuga menziesii Rob. and Fern., chronologies and its association with the ENSO in Northeastern Mexico. *Investigaciones geográficas*. 71:7-20.

Bogino S, Bravo F (2008). Growth response of *Pinus pinaster* Ait. to climatic variables in central Spanish forests. Ann. For. Sci. 65:506-518.

Bogino S, Fernández NMJ, Bravo F (2009). Climate effect on radial growth of *Pinus sylvestris* at its southern and western distribution limits. *Silva Fennica.* 43(4):609-623.

Campelo F, Nabais C, Freitas H, Gutiérrez E (2006). Climatic significance of tree-ring width and intra-annual density fluctuations in *Pinus pinea* from a dry Mediterranean area in Portugal. Ann. For. Sci. 64:229-238.

Cerano PJ, Villanueva DJ, Fulé ZP (2010). Fire reconstruction and its relation to weather in the cerro el Mohinora reserve, Chihuahua. Rev. Mex. Cie. Ftales. 1(1):63-74.

Cerano PJ, Villanueva DJ, Valdez CRD, Cornejo OE, Sánchez CI, Constante GV (2011). Historic variability of reconstructed precipitation from tree-rings for southeastern Coahuila. Rev. Mex. Cie. Ftales. 2(4):31-45.

Chen P, Welsh C, Hamann A (2010). Geographic variation in growth response of Douglas-fir to inter-annual climate variability and projected climate change. Global Change Biol. 16:3374-3385.

Cleaveland MK, Stahle DW, Therrell MD, Villanueva-Díaz J, Burns BT (2003). Tree-ring reconstructed winter precipitation in Durango, Mexico. Clim. Chang. 59:369-388.

CNA (2006). Water statistics in Mexico. National System of Information on quantity, quality, use and conservation of water. National Comission of Water. México. D.F. P. 201.

Constante GV, Villanueva DJ, Cerano PJ, Cornejo OEH, Valencia MS (2009). Dendrochronology of *Pinus cembroides Zucc.* and seasonal precipitation reconstruction for southwestern Coahuila: Rev. Mex. Cie. Ftales. 34:17-38.

Cook ER (1987). The decomposition of tree-ring series for environmental studies. Tree-Ring Bull. 47:37-59.

Cook ER, Holmes RH (1984). Program ARSTAN and users' manual. Laboratory of Tree-Ring Research, University of Arizona. Tucson. AZ. USA. P. 15.

Díaz SC, Therrell MT, Stahle DW, Cleaveland MK (2002). Chihuahua winter-spring precipitation reconstructed from tree-rings, 1647-1992. Clim. Res. 22:237-244.

Fritts HC (1976). Tree Rings and Climate. London, Academic Press. P. 567.

Gómez ML, Aguilar-Santelises R, Galicia L (2008). Functional types sensitivity to climate change in Sierra Norte of Oaxaca, Mexico. Invest. Geográficas 67:76-100.

González EMS, González MEYMA, Márquez L (2007). Vegetation and ecoregions of Durango. Plaza y Valdés, S.A. de C.V. México. D.F. P. 219.

Holmes RL (1983). Computer-assisted quality control in tree-ring dating and mesurement. Tree-Ring Bull. 43:69-78.

Laurent F, Vilá M (2003). Diversity patterns of plant functional types in relation to fire regime and previous land use in Mediterranean woodlands. J. Veg. Sci. 14(3):389-398.

Lebourgeois F (2007). Climatic signal in annual growth variation of silver fir (*Abies alba* Mill.) and spruce (*Picea abies* Karst.) from the French Permanent Plot Network (RENECOFOR). Ann. For. Sci. 64:333-243.

Manrique ME, Fernández C (1999). Phytoclimatic Evolution of last centuries in Spain, from dendroclimatic reconstructions. Invest. Agr.: Sist. Recur. For.: Fuera de Serie n 1 - Diciembre 1999.

Manthey, M, Box EO (2007). Realized climatic niches of deciduous trees: Comparing western Eurasia and eastern North America. J. Biogeogr. 34:1028-1040.

Pompa GM, Morales SM, Rodriguez TD (2012). Modeling of Forests Fuels Load from Dasometric Attributes in Temperate Forests of Northern Mexico. Res. J. For. 6:66-71.

Retuerto R, Carballeira A (2004). Estimating plant responses to climate by direct gradient analysis and geographic distribution analysis. Plant Ecol. 170(2):185-202

SAS (Statistical Analysis System) (2004). SAS User's Guide Statistics. Release 9.1. SAS Institute Inc. Cary, North Carolina. USA. p. 2170.

Seager R, Ting M, Davis M, Cane M, Naik N, Nakamura J, Li C, Cook E, Stahle DW (2009). Mexican drought: an observational modeling and tree ring study of variability and climate change. Atmósfera 22(1):1-31.

Stahle DW, Villanueva-Díaz J, Burnette DJ, Cerano-Paredes J, Heim RR, Fye FK, Acuña-Soto R, Therrell MD, Cleaveland MK, Stahle DK (2011). Major Mesoamerican droughts of the past millennium. Geophys. Res. Lett. 38(L05703):1-4.

Stokes MA, Smiley TL (1968). An introduction to tree-ring dating. University of Chicago Press, Chicago. USA. P. 73.

Villanueva-Díaz J, Fulé PZ, Cerano-Paredes J, Estrada-Avalos J, Sánchez-Cohen I (2009). Seasonal precipitation reconstruction for windward area of Sierra Madre Occidental with tree rings of *Psedutosuga menziesii* (Mirb.) Franco. Rev. Mex. Cie. Ftales. 34(105):37-69.

Villanueva-Díaz J, Stahle DW, Luckman BH, Cerano-Paredes PJ, Therrell MD, Cleaveland MK (2007). Winter-spring precipitation reconstructions from tree rings for northeast Mexico. Climate Change 83:117-131.

Yen H, Wensel L (2000). The relationship between tree diameter growth and climate for coniferous species in northern California. Can. J. For. Res. 30:1463-1471.