Functional trait variation of *Quercus castanea* Née along a climate gradient in the Cuitzeo Basin, Michoacan, Mexico.

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Figure 1. *Quercus castanea*

INTRODUCTION

Phenotypic variability is a fundamental attribute of tree species and is the product of genetic, geographic and environmental factors, and their interaction. Q*uercus castanea* (Figure 1) is a Mexican red oak with a wide geographical and altitudinal distribution that occupies contrasting environments. Locally it is the most abundant oak species in the Cuitzeo basin, in Central Mexico.

This basin has an area of about 4000 km^2 and shows a highly heterogeneous climate, topography and vegetation. In general, annual precipitation increases and mean annual temperature decreases from north to south of the basin (Figure 2) (Mendoza *et al.,* 2006; Leal-Nares *et al*., 2010). We hypothesized that climate gradients across the distribution of *Q. castanea* within the basin promotes functional trait variability between different populations either through phenotypic plasticity or local adaptation.

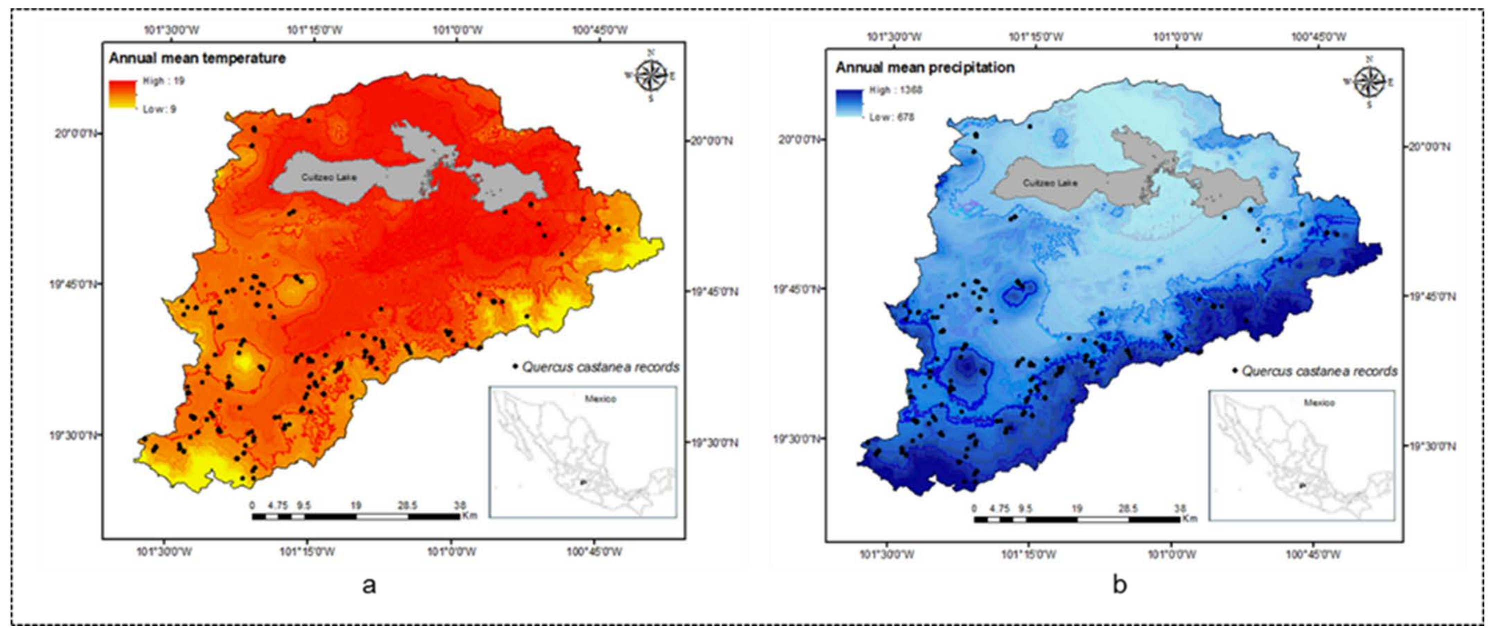

Figure 2. Climate gradients in the Cuitzeo lake basin and the distribution of the *Q. castanea* populations (black dots); a) annual mean temperature, b) annual mean precipitation.

OBJECTIVES

The objectives were: i) to evaluate the amount and patterns of phenotypic variation in a set of morphophysiological traits across *Q. castanea* populations at a landscape level in the Cuitzeo basin, and ii) to determine which traits show significant associations with environmental variables.

METHODS

We quantified leaf chlorophyll concentration, leaf mass, leaf area, leaf mass per area (LMA), leaf thickness and the Huber value (the ratio between the sapwood area and the leaf area) in 209 individuals from 22 populations of *Q. castanea* throughout the basin and associated trait variation with 19 bioclimatic variables derived from monthly precipitation and temperature values (period 1910-2009, high-resolution 30 m), soil water holding capacity and the United Nations Environmental Programme (UNEP) aridity index (Figure 3).

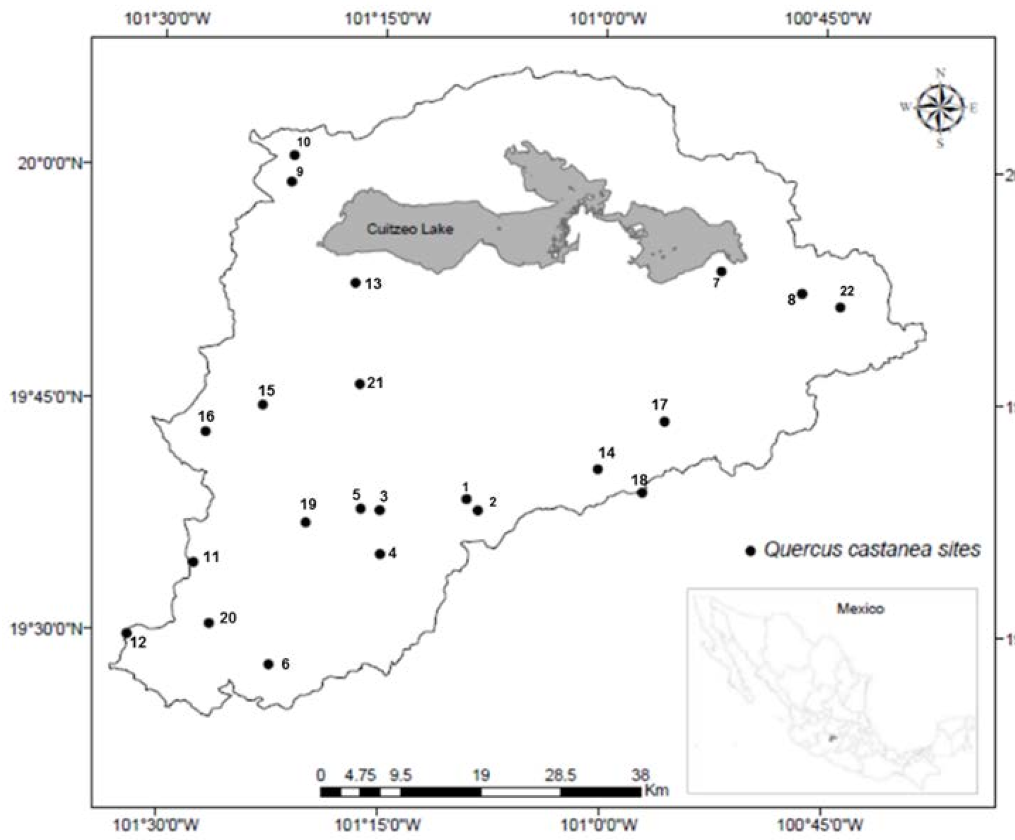

Figure 3. Cuitzeo lake basin and the distribution of the 22 *Q. castanea* populations sampled.

To know which functional traits have the highest variation between the populations sampled, we performed a canonical discriminant analysis. To separate the effects of geographic distance and local climate on phenotypic variation we performed a Redundancy Analysis (RDA) (Van den Wollenberg, 1977). We also performed a Mantel and a partial Mantel test to assess if the functional trait variation is associated with environmental variables while controlling for the potential effects of geographic distance (Mantel, 1967).

RESULTS

Even at the relatively small spatial scale of the Cuitzeo basin, we were able to detect several significant associations of the traits measured with environmental variables. The strongest variation found among populations was in leaf mass, leaf thickness and Huber value (Table 1). Mean annual temperature (B1), isothermality (B3) and soil water holding capacity (WHC) are the variables that had the major effect on the functional traits (Figure 4). The Mantel test did not indicate a correlation between the Euclidean distances of functional trait variation among populations (calculated including only leaf thickness, Huber value and leaf mass) and geographic distance (r = 0.08, P = 0.249). However, there was a significant correlation between functional trait distance and environmental distances (r = 0.29, P = 0.02). The partial Mantel test confirmed the association of these traits with environmental similarity independently of geographical proximity among populations (r = 0.29, P = 0.024).

Table 1. Canonical discriminant analysis for six functional traits in *Q. castanea.*

	Canonical 1	Canonical 2
Canonical Eigenvalue	4.3	1.04
Percent (%)	67.9	16.4
Cumulative percent (%)	67.9	84.3

Functional trait	Scoring coefficients	
Chlorophyll concentration	-0.013	-0.139
Leaf mass	-25.109	**21.123**
Leaf area	0.309	-0.174
Leaf mass per area	-0.105	0.077
Leaf thickness	**64.66**	-8.389
Huber value	**27.688**	**-128.443**

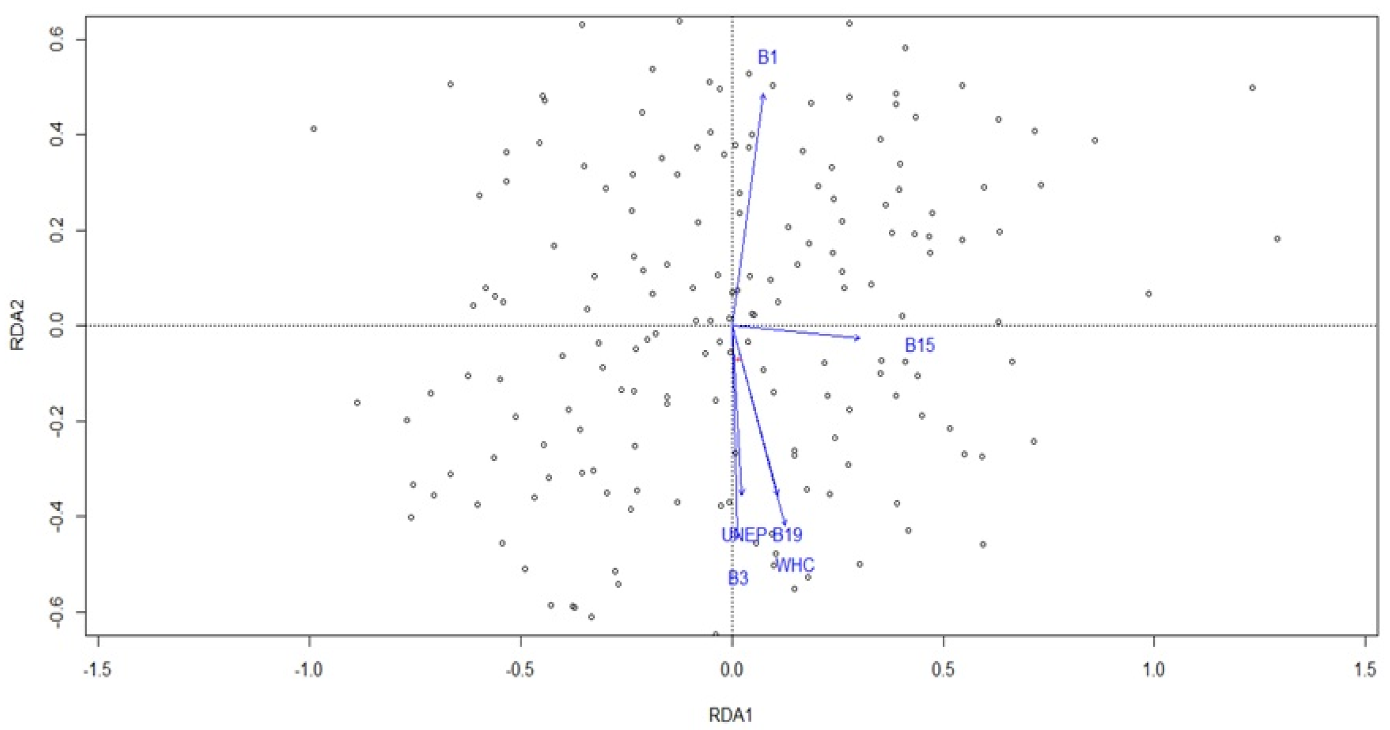

Figure 4. Redundancy analysis between the functional traits and climatic variables conditioned by latitude and longitude. Dots represent the individuals of the 22 populations sampled. Climatic variables: mean annual temperature (B1), isothermality (B3), precipitation seasonality (B15), precipitation of the coldest quarter (B19) soil water holding capacity (WHC), UNEP aridity index.

CONCLUSIONS

- While previous studies have considered functional variation in oak species at a whole-range level, we have shown that significant functional differences exist among populations of *Q. castanea* separated by a few kilometers in the heterogenous landscape of the Cuitzeo basin.
- This species shows clearly sclerophyllous leaves, but leaf thickness and LMA vary to a considerable degree across populations. Whether this variation is due to local adaptation, plasticity or a combination of both will be clarified in ongoing common garden and landscape genomics studies.
- *Q. castanea* follows a pattern resembling more a tropical than a Mediterranean species. We hypothesize that phenological patterns (i.e. degree of deciduousness) in this species should be negatively associated with LMA along populations in the Cuitzeo basin, but this should be evaluated in further studies.

LITERATURE CITED

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