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Deliverable D3.7

Estimation of GCUs adaptability (quantitative genetics linking trait proxy and genomics) for at least one species

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TABLE OF CONTENTS

TABLE OF CONTENTS

1   Summary

The ultimate goal of WP3 is to forecast the adaptability of forest genetic resources. One approach employed to reach that goal is to use quantitative-genetic theory (Task 3.4), combined with the measurements of adaptive traits to predict the adaptability of the genetic conservation units (GCUs). This approach requires the integration of adaptive traits (both "soft" and "hard" traits, that is, those that are more and less driven by plasticity caused by environmental conditions, respectively), together with genomic (to control for relatedness among individuals) and environmental (to control for site heterogeneity) data. We present here the output for the black poplar (*Populus nigra*). Output in the Spanish GCU revealed significant selection gradients for two morphological and one physiological trait, with differences among sexes in the magnitude and direction of some of the selection gradients. In general, selection gradients were stronger for females, which, coupled with higher heritability for most traits, suggest stronger response to selection for females than males in this population. A comparison of this result with the other GCU in Austria will shed light on the commonality of this pattern.

2   Introduction

To be able to use quantitative genetic model to predict the GCUs adaptability, three main datasets are needed, which are produced via different technologies and partners (see D3.2): adaptive traits produced in WP2 (hard traits) and WP3 (soft traits), genomic data produced in WP4 and environmental data produced in WP3 via unmanned aerial vehicle.

Despite being a central issue in evolutionary ecology, estimating adaptive capacity is challenging. An often-used first approximation is to estimate the amount of additive genetic variance in a population, which in turn, informs on the *heritability* of the traits (i.e., the proportion of the phenotypic variance that is genetically determined and able to respond to natural selection). The other relevant component of the response to selection are *selection gradients*, which define the relationship between the traits and individual's relative fitness. Importantly, the two components of the response to selection (i.e., heritability and selection gradients) can be biased by different factors, such as environmental and spatial effects that can affect traits, fitness and genetic relations, the covariance of traits - altogether they can enhance or limit the response to selection among others. As result, it is of prime importance to take into account these sources of error and advocate for a very careful statistical procedure.

In this Deliverable we present preliminary analysis of heritability and selection gradients for univariate phenotypic traits in the Spanish *Populus nigra* GCU. The methodology employed here is expected to be easily applicable to the other GCUs included in WP3 once complete and curated datasets are available.
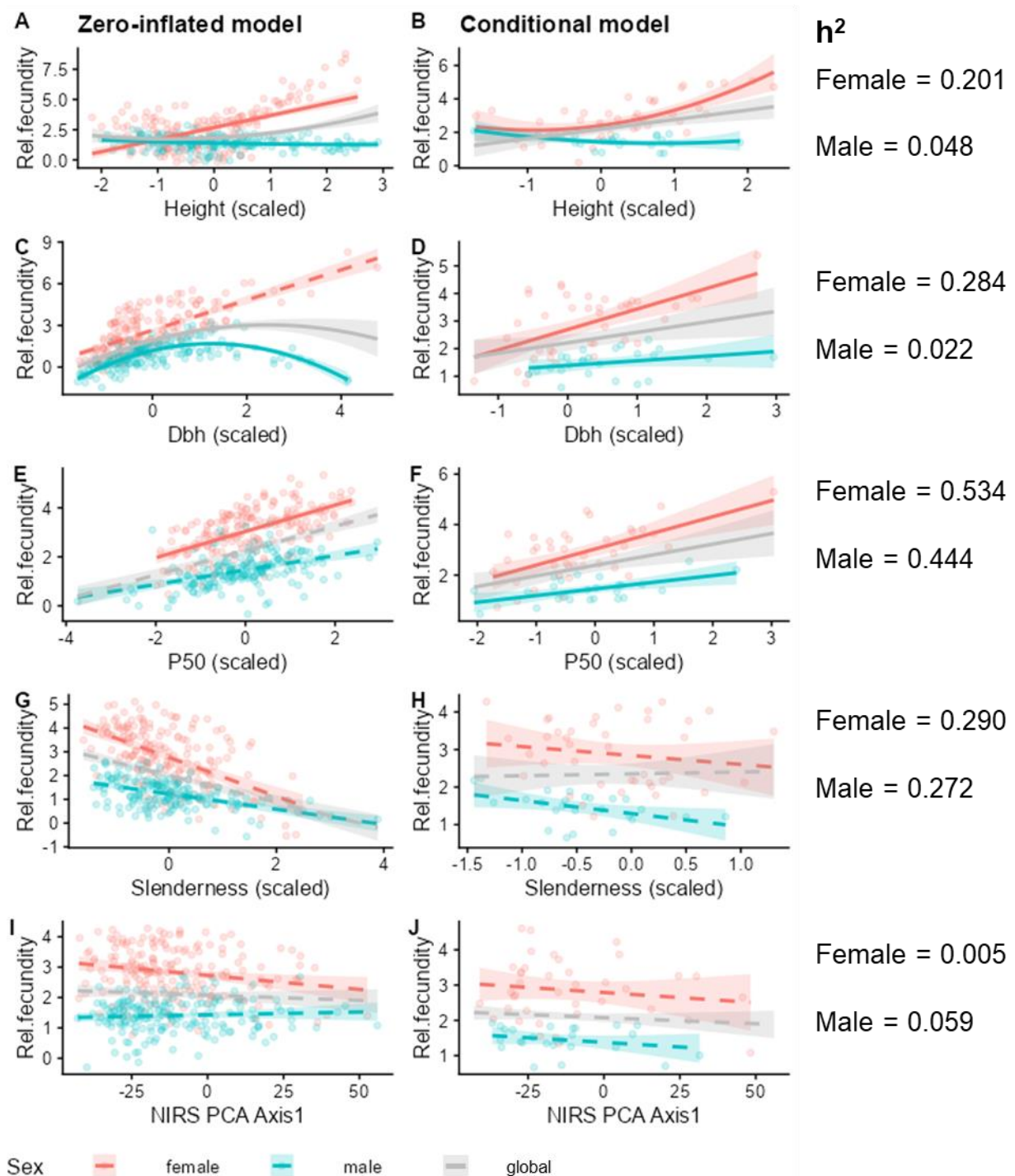
3   Results

We estimated partial linear and quadratic regression coefficients of individual relative fitness on the traits with generalized models. Individual relative fitness was estimated for the 500 adult trees as relative realized fecundity by the NMπ method (see D3.5). Given the high proportion of individuals with non-significant fecundity, zero-inflated models where employed to properly account for the distribution of the data. All models included environmental covariates collected by UAV flights (i.e. soil water content, soil temperature and elevation, Normalized Difference Vegetation Index (NDVI) and the spatial autocorrelation of fitness; see D3.2).

Selection gradients were estimated for three morphological traits, namely, tree height (H), tree diameter at breast height (dbh) and slenderness index (SI = H/dbh) and one physiological trait representing the water potential at which 50% stem conductivity is lost (P50, measured in WP2; see D3.2). Finally, we considered the NIRs spectra as a trait itself by performing PCA analysis to check its potential utility as a compound trait and evaluate its adaptive potential. For the dioecious species *Populus nigra*, analyses were preformed for all individuals, as well as for females and males separately.

Considering all individuals in the population, results show significant selection gradients for height, dbh and the conditional part of the model of P50, while non-significant selection gradients were found for Slenderness and the NIRs PCA (Figure 1). We found differences among sexes for the conditional part of the models for all traits. In males, quadratic selection gradients for height indicate that individuals with intermediate values had lower realized fecundity than taller or shorter ones, while for females, taller individuals presented more probability to have offspring (both for the zero-inflated and the conditional parts of the models) (see Figure 1). In the case of dbh, males with intermediate diameter show higher probability of having offspring in the zero-inflated model, while males with larger diameter have more offspring in the conditional model. For females, thicker individuals with larger diameter present more probability of having more offspring in the conditional model. Higher values of P50 are selected in females, and in the conditional model of males. Thus, individual with lower vulnerability to drought (higher P50) are selected in this population.

Finally, heritability estimates (h^2) for the studied traits fall within the range of values for forest trees, with females generally displaying higher heritability than males. P50 (vulnerability to drought) shows the highest h^2 value and is therefore the trait that is best able to respond to natural selection (Figure 1).

Figure 1. Preliminary results on the Spanish *Populus nigra* GCU selection gradients and heritability estimates by sex. Linear and quadratic selection gradients of the final models are presented for the zero-inflated part of the model (left panels) and conditional part of the model (right panels) and heritability estimates (right annotations) for height (A, B), dbh (C, D), P50 (E, F), Slenderness (G, H), and Axis 1 of the NIRs spectra PCA (I, J). Solid and dashed lines indicate significant and non-significant regression coefficients, respectively.

Deviation from the original timeline. In this Deliverable we present the output only for the Spanish GCU of *Populus nigra* for which most of the data were available to conduct the full workflow of analyses. The approach we used is easily transferable to the other GCUs as soon as the three curated datasets will be available. Delays in data production have been linked to various reasons (both species specific and common across species) including, bad field conditions, administrative delays, technological challenges, genotyping facilities delay, laboratory supplies out of stock, extra genotyping for sex determination in poplar (see D3.2). To mitigate for these delays, we opted to work on two species in parallel (*Pinus pinaster* and *Populus nigra*) instead of focusing on one species. We foresee to have the complete datasets for these two species by the end of 2023- beginning of 2024. Overall, tasks are progressing adequately in WP3, despite the many hurdles encountered during the project progress.

4 Conclusions

Overall, we have found significant selection gradients for two morphological and one physiological trait, with differences among sexes in the magnitude and direction of some of the selection gradients. In general, selection gradients were stronger for females, which, coupled with higher heritability for most traits, suggest stronger response to selection for females than males in this population. A comparison of this result with the other GCU in Austria would shed light on the commonality of this pattern.

5 Partners involved in the work
INIA-CSIC, CETAMAS, CITA, INRAE, CREAF, CNR, UMR

6 Annexes