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# Post-glacial re-colonization and natural selection have shaped growth responses of silver fir across Europe

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Warmer climate and more frequent extreme droughts will pose major threats to forest ecosystems. Persistence of intra-specific populations of tree species will depend on their tolerance and adaptive capacities to forthcoming climate conditions. However, past demography processes due to post-glacial recolonization can also contribute to the genetic-based differences in growth responses among provenances. In this study, we investigated the impact of climatic conditions on growth traits among 18 provenances of silver fir (*Abies alba* Mill.) from west, south and eastern Europe growing in two provenance trials established in Switzerland in 1980s. We further assessed whether the differences in growth-related traits across provenances were linked to their genetic differences due to recolonization history and natural selection processes.

In total 250 individuals were measured and cored for dendrochronological analyses, and different growth-related traits were calculated: i) total tree height and diameter at breast height (DBH), ii) growth-climate relationships using correlations between tree-ring width and monthly climate parameters as well as levels of autocorrelation, and iii) short-term responses to extreme drought using resilience components (resilience, resistance, and recovery) to the severe drought that occurred in the study area in 2003. We also genotyped all the individuals in 150 putatively neutral single nucleotide polymorphisms to define the neutral genetic structure of the population, the neutral genetic differentiation among provenances ($F_{ST}$) and the genetic variation among provenances in relation to the total genetic variance in a trait ($Q_{ST}$). Signs of natural selection were assessed by two approaches: i) Pearson correlations between the least-square means of provenances of the traits and bioclimatic variables from the seed origin, and ii) $Q_{ST}$-$F_{ST}$ comparison.

The studied provenances grouped into three longitudinal clusters reassembling the genetic lineages of refugia from the last glacial maximum: the provenance of the Pyrenees as a sole member of the westernmost cluster, the Central European provenances representing the central cluster and all the eastern European provenances forming the eastern cluster. These three lineages showed differences in growth performance traits (height and DBH), with the trees from the eastern cluster being the top performers. The Pyrenees cluster showed significantly lower

recovery and resilience to the extreme drought of 2003 as well as lower values of growth autocorrelation. A $Q_{ST}$-$F_{ST}$ and correlation analyses with climate of provenance origin suggest that the differences among provenances found in some traits result from natural selection. Our study suggests that post-glacial re-colonization and natural selection are the major drivers explaining the intra-specific variability in growth of silver fir across Europe. These findings provide insights to support assisted gene flow to ensure the persistence of the species in European forests.