

Differences in drought response of *Pinus sylvestris* L. and *Quercus pubescens* Willd. in the Swiss Rhône valley

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Introduction

During the second half of the 20th century, many processes have altered the species composition in the low-elevation (<1200 m a.s.l.) forests in the inner-Alpine dry valley Valais, which is located in the southwest of Switzerland. In the past, the pioneer Scots pine (*Pinus sylvestris* L.) benefited from historical forest managements, such as goat grazing, selective withdrawal of forest products and timber harvesting (Rigling & Cherubini 1999). In recent decades, deciduous species, in particular pubescent oak (*Quercus pubescens* Willd.), have spread as a result of the abandonment of past forest use and ongoing natural succession. In the mean time, the climate has changed towards longer summer drought periods, higher mean temperatures (Rebetez & Dobbertin 2004) and different seasonality for moisture availability. The direct and indirect effects of the factors mentioned above are believed to have led to the locally high mortality rates of pine. In this study, we investigate the differences between pine and oak in their growth response to moisture conditions along altitudinal gradients, to evaluate the influence of climate change on species composition.

Material and Methods

On each of the five chosen altitudinal gradients, three mixed pine and oak sampling plots were studied. For each of the 15 plots, all the trees on an area of 12 m in radius were cored using an increment corer, taking two cores at breast-height to conduct the dendro-chronological analyses and one core at the base of the tree to count the age. After measuring and crossdating the tree-ring widths, standard and residual chronologies were produced, by applying standard procedures in the ARSTAN software package (Cook 1985, Holmes 1994). Response functions, i.e. a multiple regression after extracting the principal components of the climatic predictors, were then calculated using the routine PRECON (Fritts et al. 1991), with the residual chronologies as the dependent variable and the monthly moisture availability from June_(i-1) of the previous to September_(i) of the current year as the independent variables. Moisture availability (Ppot) was calculated as the difference between precipitation and potential evapotranspiration (Thorntwaite 1948). This index was used to arrive at a functional interpretation of the response functions. The analysis was performed over the last 50 years. Two plots had to be excluded from the analysis, because the trees were all younger than 50 years old.

Finally, to point out the species-specific response to moisture, we recorded the percentage of the chronologies responding significantly ($p < 0.05$) to moisture availability, for each month and for the two species separately. For a regional differentiation of the response patterns, the 16 regression coefficients of the 13 plots were introduced into a principal component analysis (PCA) with the statistic software R (Ihaka & Gentleman 1996).

Results and discussion

Species-specific response to moisture

Our results revealed a species-specific response to moisture (Fig. 1), which can be interpreted in terms of different physiological adaptations to climatic patterns in general and to rather dry site conditions in particular.

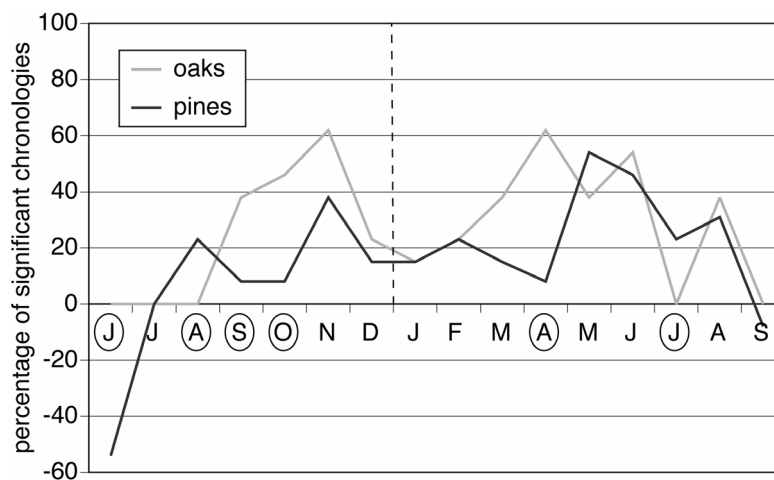


Figure 1: Summarised growth response to the monthly moisture index P_{pot} . Percentage of chronologies with a significant ($p < 0.05$) negative or positive response of pines and oaks from June_(i-1) to September_(i) are shown. 100% = 13 chronologies. Circles indicate significant differences between oak and pine ($p < 0.05$).

The oaks showed responses to moisture availability from September to November in the previous year. Such response patterns can be explained by a physiological preparation for the next growing season including 1) the storage of metabolic compounds and 2) root growth. The growth of fine roots in autumn and winter may be advantageous in summer-dry climates (Cherubini et al. 2003) and is reported to occur in *Quercus* spp., if soil temperatures are above 0°C (Hoffmann 1974, Teskey & Hinckley 1981). Pines, in contrast, only showed responses to moisture in August and November of the previous year. However, the explained variance of prior growth in pine (originating from response functions with standard chronologies) was much higher than that in oak. These results for pine are quite common in coniferous species (Kienast et al. 1987, Oberhuber et al. 1998, Rigling et al. 2002) and thought to be related to 1) the photosynthetic activity of the needles over more than one year, which causes a lag-effect and 2) the arrangement of shoot length and needle buds in the

previous August. In the current year, oaks started their response with a peak in April already, while pines did not respond before May, but still showed a response in July, the driest month in the year. Thus, oak seemed to react consistent with Mediterranean species with a summer stop of activity, whereas pine as a sub-boreal species was still exposed to the very dry conditions.

However, whether this result for pine points at the need of a prolonged growth period until July (meaning that pine is less well-adapted to such a climate regime), or whether it shows the benefit of being capable to grow in very dry conditions, has to be further investigated on a physiological level. From our point of view, in such dry conditions the former seems more likely.

Overall, oaks appeared to have fewer problems to adjust their physiological activity to times, when sufficient moisture is available (spring and autumn). Given a change in the seasonality of moisture availability towards longer summer drought periods, the risk of cavitation in pines (Martinez-Vilalta et al. 2004) is likely to increase in the future.

Regional differentiation in the response to moisture

Besides the species-specific response to moisture, we found a sub-regional differentiation of the response to moisture availability. For both species, the PCA of the regression coefficients resulted in three groups of similar response patterns: the side-valley plot Eschwald, the south facing plot Eggerberg and the rest of the plots, which are all situated in the lower valley. The plots Eschwald and Eggerberg belong to the more continental Visp region, where the trees showed more pronounced responses compared to the more oceanic Sion region.

From our sampling design, we would have expected an altitudinal differentiation of the response patterns. However, it seems that the sub-regional site conditions such as climate and soil texture, are mainly influencing the growth response of the trees on our study plots.

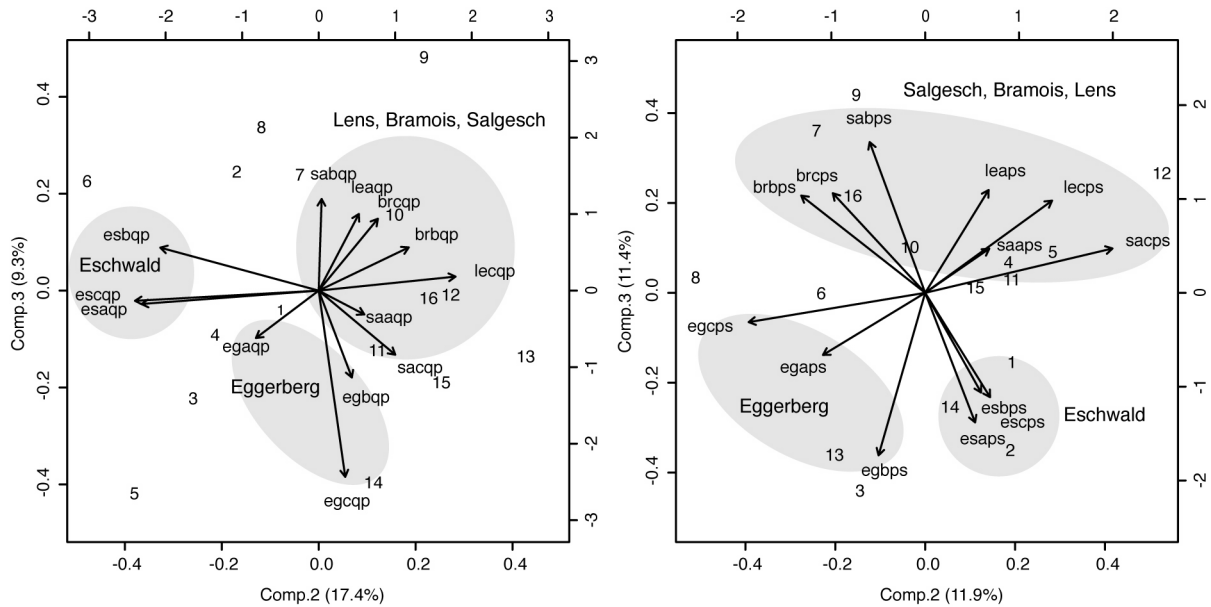


Figure 2: PCA of response to moisture index P_{pot} for oak (left) and pine (right) (second and third component axes). Eschwald and Eggerberg belong to the Visp region, Salgesch, Lens and Bramois belong to the Sion region. Numbers 1-16 stand for the months from June_(i-1)=1 to September_(i)=16; January_(i)=8

Acknowledgements

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