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Dry Matter Allocation in Treeline Trees

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Summary

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Here we present data from the first systematic study of dry matter allocation in treeline trees in response to elevation. We excavated 23-year old trees across a 140 m elevational transect at the central alpine treeline of Switzerland. Results show equal (Larch) or heigher investments (Pines) in leaves at the upper compared to the lower end of the transect. Total biomass does not, but tree height does decline with elevation, which is explained by increasing branch/stem ratio. These data do not suggest an increased burden of the C-balance of trees near treeline by a greater non-assimilating tissue fraction.

Introduction

The carbon balance of plants strongly depends in allometric traits such as leaf mass ratio (LMR; the dry matter of leaves per total plant mass in %) or root mass ratio (RMR; the dry matter of roots per total plant mass in %). It is still unclear what is causing treeline (see review by KÖRNER 1998). While a great deal of knowledge has been accumulated on gas exchange characteristics of treeline trees (TRANQUILLINI 1979, HÄSLER 1984) very little is known on allocation, which is of equal significance. If the tree carbon balance plays a role, it would be central to know the C-investment "policy" of treeline trees in addition to photosynthesis and respiration. We utilized the rather unique situation of a large, 23 year old afforestation trial, where equally aged, uniform provenance trees could be studied in a common environment typical for the alpine treeline (Fig. 1).

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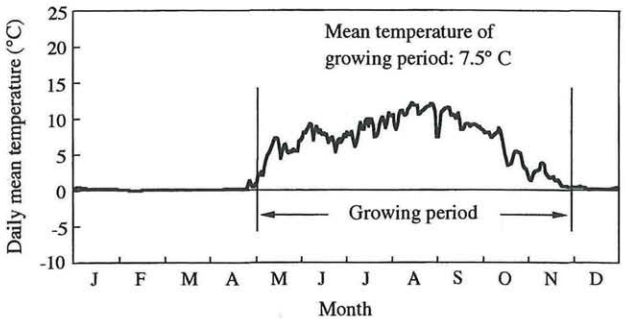

Fig. 1. The annual course of ground temperature (-10 cm) in the shade of trees at Stillberg Davos, 2080 - 2230 m. Original data for the period June 1997 - June 1998 measured by a buried data logger (Tidbit, Onset computer corp., USA). Measurements by four other loggers spread across the 180 m elevational transect did not reveal a consistently different picture, hence microhabitat was more influencial on root zone temperature than difference in elevation by ±70 m.

Methods

We excavated 25 individuals of *Pinus cembra*, *Pinus uncinata* and *Larix decidua* across a 140 m elevational transect between 2080 and 2220 m elevation in the Swiss Alps at Stillberg near Davos (SCHÖNENBERGER & FREY 1988) 23 years after they were planted. The afforestation was established by the Swiss Institute of Forest, Snow and Landscape (WSL). Uppermost native adult trees in this area are found at ca. 2180m elevation. The central problem of tree harvesting was root excavation. Although we were fairly successfull in root recovery, we utilized a root diameter/dry mass ratio (not shown) to reconstruct the terminal lost root mass of broken roots. However, in terms of mass, losses were so small that statistics were not affected had we not applied this correction. All data refer to oven dry weight (80°C).

Results and Discussion

23 year old trees at treeline invest roughly 2/3 of their biomass in stems and branches (Fig. 2). Approximately 15% (evergreen) and 7% (deciduous) of total tree biomass is allocated to green leaves (LMR). Roots, though exhaustively represented in our data, comprise a surprisingly small fraction of only 10% to 15%. Elevational trends in allocation (Fig.3) are weak or not existent for roots, but a significant increase in LMR was observed in both *Pinus* species from around 10% at the lower end to around 20% at the upper end of our 140 m elevational transect (no effect in larch).When trees were younger (6 years old) TURNER & al. 1982 found much higher leaf mass ratios of 33% in *Pinus montana* and even 47% in *Pinus cembra* in the middle of our transect. The root mass ratio by that time was 22% in *Pinus montana* and 20% in *Pinus cembra*, which is less different from the current situation.

Surprisingly, total tree biomass (Fig. 4) shows no elevational trend. Microhabitat conditions appear to over-shadow elevation effects. In contrast, tree

height (Fig. 5) declines significantly in pine, and marginally significant in larch. We explain this height-biomass discrepancy by the observed (Fig. 2) increase of branch/stem ratios with increasing elevation (only significant in *P. cembra* and *L. decidua*, data not shown).

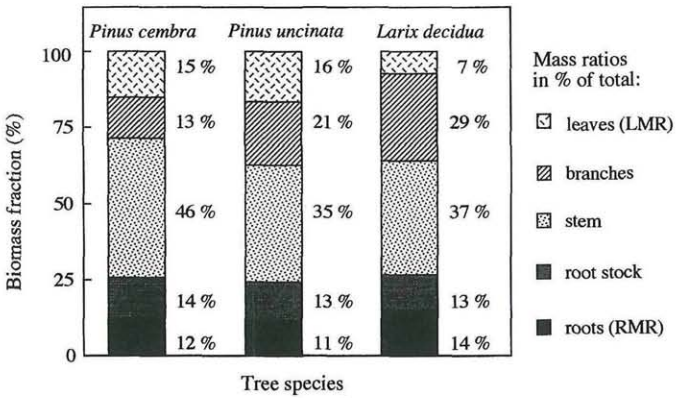

Fig. 2. Dry matter allocation to five biomass compartments of *Pinus cembra* (n=24 individuals), *Pinus uncinata* (n=20) and *Larix decidua* (n=20).

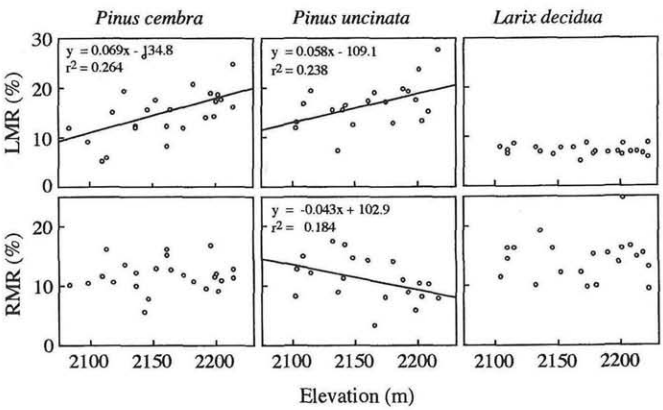

Fig. 3. Leaf mass ratio (LMR) and root mass ratio (RMR) of trees in relation to elevation within the treeline ecotone.

Conclusion

As one approaches the upper limit of tree growth, trees do not invest more in heterotrophic structures, in Pines the autotrophic/heterotrophic ratio even increases.

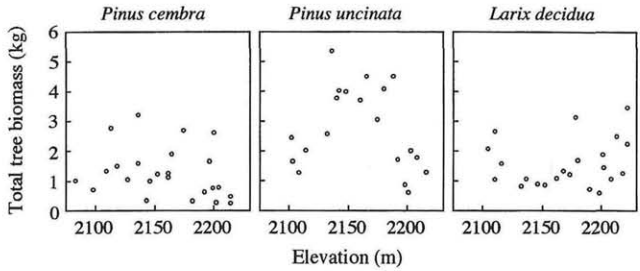

Fig. 4. Total individual dry matter of trees in relation to elevation (23 years after afforestation).

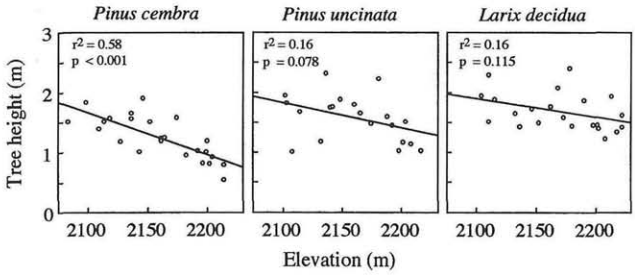

Fig. 5. Individual tree height in relation to elevational within the treeline ecotone transect.

This may result from more stunted morphology (shorter stems, more branches; Fig. 6) possibly related to greater thermal limitation of apical versus lateral growth (the latter near the warmer ground layer). What ever limits tree growth at treeline, it does not seem to be related to a disadvantageous green to non-green dry matter investment.

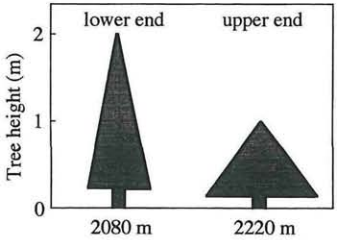

Fig. 6. Illustration of the more stunted shape of trees as one approaches the upper end of the elevational transect (smaller tree height at equal biomass).

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