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Shoot and Root Growth of Young *Larix decidua* in Contrasting Microenvironments Near the Alpine Timberline

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Summary

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Shoot and root elongation of young European larch (*Larix decidua*) growing in natural soil on E- and N-facing slopes (2180m a.s.l.; inclination 40°) at the Stillberg experimental area (near Davos, Switzerland) were measured during the vegetation periods 1988-1990.

Growth and mean growing period are greatly influenced by the microclimate. In spring, roots start growth 3 to 5 weeks earlier than the shoots; shoot elongation ceases at the end of August, whereas root growth continues until temperatures decrease. Shoot and root growth are correlated to air and soil temperature. Root growth increases faster with temperature than shoot growth.

Introduction

In the Alps, many avalanches start below the theoretical timberline. Reforestation of these slopes could prevent avalanche damage, but tree plantation often fails at these extreme sites. To investigate the problems of afforestation at high elevation, test plantations were made at the Stillberg experimental area near Davos.

During the first years after plantation, growth is mainly controlled by the microclimatic conditions (SCHÖNENBERGER & FREY 1988). Near the timberline, the microclimate is strongly related to the exposition and topography of the site

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(TURNER 1988). First measurements of shoot and root growth of young *Pinus mugo uncinata* trees were performed between 1977 and 1979, and of *Pinus cembra* between 1981 and 1983 (TURNER & al. 1982, TURNER & STREULE 1983, TURNER & STREULE 1988). Another important tree at the timberline in the Central Alps is *Larix decidua*. The presented shoot and root growth analysis of this species was performed between 1988 and 1990.

All growth investigations at Stillberg are part of a larger tree planting program within the timberline ecotone. Its objective is afforestation in the starting zones of avalanches.

Material and Methods

Study sites: E- and N-facing slopes of an avalanche gully (2185m a.s.l.; inclination 40°) at the Stillberg experimental area (46°46'27" N; 9° 52' 07" E) near Davos, Switzerland (precipitation 1098mm y^{-1}). Some site factors of the different exposed slopes are given in Table 1.

Table 1. Vegetation, soil and microclimatic conditions on E-facing and N-facing slopes at the Stillberg experimental area. Net radiation (measured 1980-1982) and temperature (measured 1988-1990) data are mean values of 3 years.

Stillberg, 2180 m a.s.l.		E-facing slope	N-facing slope
Vegetation		Junipero-Arctostaphyletum	Empetro-Vaccinietum
Soil		Ochre podsol	Iron-humus podsol
Acidity (0 - 0.25m)		pH 3.0	pH 2.8
Net radiation	annual	2120 Wh m^{-2}	1098 Wh m^{-2}
	January	352 Wh m^{-2}	129 Wh m^{-2}
	July	4149 Wh m^{-2}	2851 Wh m^{-2}
Air temperature	annual	3.1°C	2.2°C
	January	-2.2°C	-1.7°C
	July	10.8°C	9.5°C
Soil temperature	annual	4.0°C	2.3°C
	January	-0.5°C	-0.5°C
	July	11.0°C	8.5°C

Plant material: *Larix decidua* Mill. trees (seeds provenance Bos-Cha, Engadine; 1700-1800m a.s.l.; S-facing slope) were grown in the nursery at Birmensdorf, 550m a.s.l., in 1987. On both experimental sites, 10 one-year-old seedlings were planted at the end of May 1988 in the natural soil behind acryl glass windows for root observation. At this time, all plants were still in winter dormancy. After planting, about one third of the total roots were visible at the window. The glass plates were insulated by 0.1m thick, non-translucent "Flumroc" insulating plates to maintain ambient conditions. For three years (1988-1990), the elongation of the terminal shoot, 3 lateral shoots and of all visible roots was measured every week at orange dimmed light throughout the growing season.

Air temperature (at +0.1m) and soil temperature (at -0.1m) were measured by means of platinum resistance thermometers which were scanned every 5 minutes throughout the length of the experiment.

Results

In the first year, there were about ten times more visible growing root tips than in the following years (Fig. 1). In general, on the E-facing slope, many more root tips showed elongation than on the shadowed N-facing slope. This changed only during the second part of the growing season in the later years.

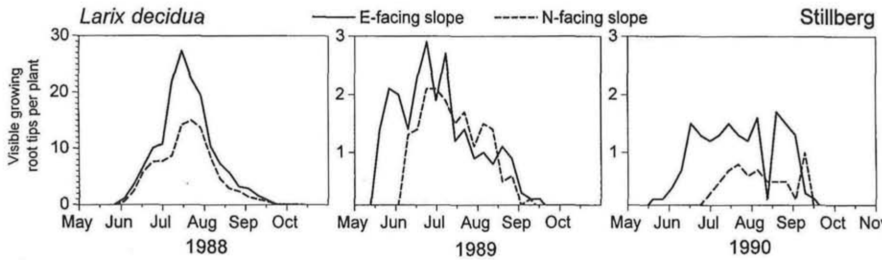

Fig. 1. Weekly observed number of actively growing root tips of young *Larix decidua* trees on E- and N-facing slopes.

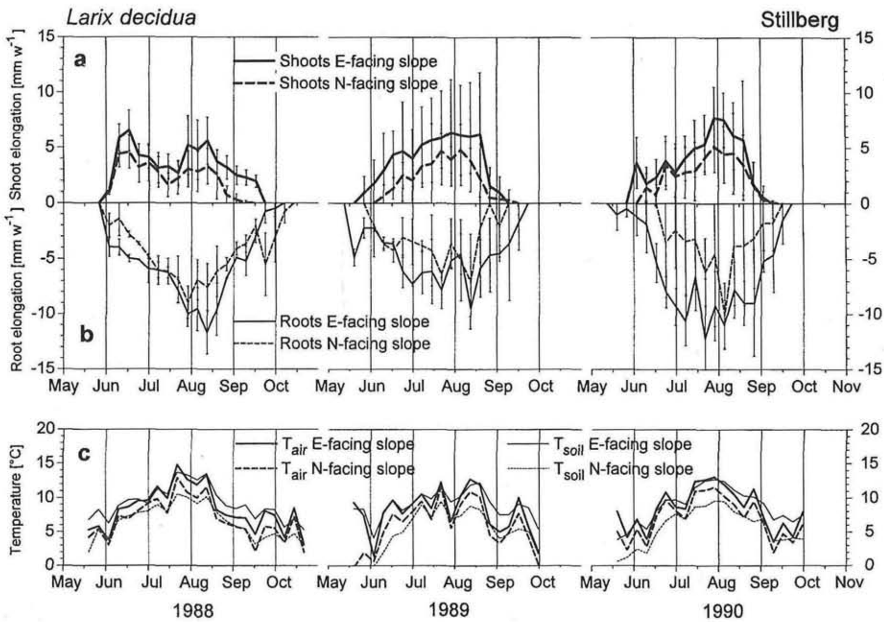

Fig. 2. Longitudinal growth of shoots (a) and roots (b) of young *Larix decidua* trees on E- and N-facing slopes near the alpine timberline [mm per week], and the corresponding weekly mean air and soil temperatures (c). For the first year, the error bars are based on a total of 200-300 root tips, in the following years on 20-30.

Shoot and root elongation growth were markedly greater on the E-facing than on the N-facing slope (Fig. 2 a,b). Apart from the year of plantation, root growth started earlier in spring and ceased later in autumn than shoot growth. On the E-facing slope, the growing season was 3 to 4 weeks longer than on the N-facing slope. If temperature drops below a certain limit (i.e. 5° to 7°C), shoot and root growth are visibly reduced (Fig. 2 a-c).

The relation between growth and temperature is shown in Fig. 3. Shoot and root elongation are correlated with air and soil temperature respectively. Root growth increases faster with ambient temperature than shoot growth. Shoot growth of the trees on the E-facing slope is somewhat higher than that on the N-facing slope, but the difference is not significant.

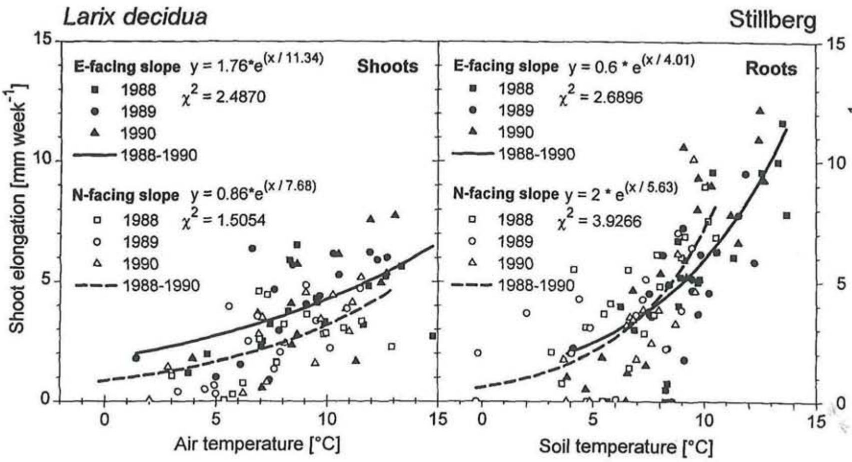

Fig. 3. Weekly shoot (a) and root (b) growth of young *Larix decidua* trees, in relation to air and soil temperature (at +0.1m and at -0.1m) respectively, on E-facing and N-facing slopes near the alpine timberline [mm per week] for 1988-1990, and regression lines for exponential growth.

Discussion

After one year of growth on the experimental site, the number of visible growing root tips was the same as found for *Pinus cembra* and *Pinus mugo uncinata* by TURNER & al. 1982 at the same site. The large number of growing root tips in the planting year of the *L. decidua* trees was probably due to the growing conditions in the nursery at low elevation, where *L. decidua* produced many more roots than *P. mugo*, which was grown at the same nursery.

The root growth period of the *L. decidua* was longer than that of *P. cembra* and *P. mugo*. The evergreen tree species stopped shoot growth between the middle and end of August (TURNER & STREULE 1988), whereas *L. decidua* shoots continued elongation into September. For all the tested species, root and shoot growth were much higher on the E-facing slope than on the N-facing slope. The relatively low photosynthetic rates on the colder N-facing slope may partly explain these findings (HÄSLER 1982, 1985). HAVRANEK 1972 also showed the dependence of photosynthetic rate on soil temperature.

The low temperatures at the timberline seem to be one of the growth-limiting factors. Temperatures below 5° to 7°C (frost in the summer months is quite common at this altitude) reduce elongation rates for shoots and roots. Root elongation in the slowly changing temperature regime of the soil reacts more sensitively to changes in temperature than does shoot elongation (Fig. 3). Recently, temperature was also reported as one of the limiting factors for root growth at the alpine and boreal timberline by LYR 1996 for *Larix decidua* and *Picea abies*, by BALISKY & BURTON 1997 for *Picea engelmannii* and *Pinus contorta*, and by KAJIMOTO & al. 1997 for *Larix gmelinii*. Whether the reduced water uptake at low temperatures is the main limiting process, still remains an open question (cf. BALISKY & BURTON 1997).

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