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The Growth of Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) Seedlings on Hydrologically and Nutritionally Contrasting Till Soils in Finnish Lapland

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K e y w o r d s : Biomass, needle, photosynthesis, root, transpiration, water potential.

S u m m a r y

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The survival and growth of Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies*) seedlings were studied on two hydrogeologically and nutritionally contrasting types of till soil. The first study site (Vuotso) is composed of sandy till derived from granite-gneiss bedrock, and the other (Vaalolehto) from chlorite-amphibole schist. The one-year-old paper pot seedlings were planted in spring 1996 on both sites with identical study design, including two greenhouses and a control. The seedlings have grown in two temperature regimes using different ventilation intensities. Three irrigation treatments were applied. The preliminary results of seedling survival, shoot and root biomass, photosynthesis, tanspiration and water potential of the needles are presented in this paper. There were no significant differences in survival between the species. The early development of the Scots pine seedlings was much faster than that of the Norway spruce seedlings. This was seen in the rate of CO_2 fixation and accumulation of shoot biomass. The root/shoot ratio was higher in the spruce and in the yellowish pine seedlings than in the fast growing, green pine seedlings. The results suggest that the high shoot/root ratio is the factor that predispose the fast growing Scots pine seedlings to dieback on fine-textured soils with a high water and nutrient content.

I n t r o d u c t i o n

Owing to the higher productivity and timber value of Scots pine compared

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to other species, clear-cutting, site preparation and artificial regeneration of pine have been the predominant forest-regeneration activities during the past 40 years in Finnish Lapland. There have been occassional serious cases of seedling dieback, the worst failures occurring in pine regeneration areas on fine-textured soils with a thick humus layer that formerly had Norway spruce as the dominant tree species (LÄHDE 1974, POHTILA & POHJOLA 1985). Although some damage, such as frost heaving and fungus diseases, especially snow blight (*Phacidium infestans* Karst.) and Scleroderris canker (*Ascocalyx abietina* Lagerb.), have been observed in the field (MÄKITALO 1999), the primary physiological reasons for pine-seedling dieback has remained unclear. The aim of this study was to determine the effect of the contrasting hydraulic properties of till soil on the growth of Scots pine and Norway spruce seedlings. The hypopthesis is that pines are not able to grow on fine-textured till soils with a high water content.

Materials and Methods

Two hydrogeologically and nutritionally contrasting till soils were selected as the study sites. The soil type at both sites is haplic podsol. The study site in Vuotso is composed of sandy till derived from granite-gneiss bedrock. The litter and humus layer is 3-5 cm thick, the leaching zone (A) about 2 cm thick, and the enrichment zone (B) 1-2 cm thick. The content of clay and silt fractions in the parent till is 17.9 %. The study site in Vaalolehto is derived from chlorite-amphibole schist with a litter and humus layer up to 10 cm thick, leaching zone (A) 5-7 cm thick and enrichment zone (B) at least 3 cm thick. The content of clay and silt fractions in the parent till is 52 %. Field saturated hydraulic conductivity at Vuotso site is 10^{-5} m s^{-1} and that of Vaalolehto site 10^{-6} m s^{-1} (PENTTINEN 2000).

The one-year-old paper pot seedlings were planted in the field in spring 1996 at two hydrologically contrasting till sites, 50 km apart. Two plastic greenhouses at both sites were built around the seedlings. Different ventilation intensities were used in each greenhouse: 1) warm (effective temperature sum of the growing season > 1300 d.d.) and 2) cool (effective temperature sum < 800 d.d.). Three irrigation treatments in four replicates were used: a) dry (daily matric potential in Vuotso –12 …-27 kPa, in Vaalolehto –7.5…-9.5 kpa), b) medium (Vuotso –7.5 …-20 kPa, Vaalolehto –7.0 …-9.0 kpa), c) wet (Vuotso –7.0 …-13 kPa, Vaalolehto –6.5…-8.5 kpa). The control site (natural condition without greenhouse) was in Vuotso –10 … –17 kpa and in Vaalolehto –7.5 … –9.0 kPa. The above values apply both the warm and cool growing conditions.

Meteorological parameters (temperature, humidity and radiation) and soil parameters (dielectric and temperature) were measured with the automatic weather station (Vaisala) each hour. Soil matric potential was recorded with a tensiometer. CO_2 assimilation and transpiration of the needles were measured by IRGA (ADC-LCA). The preliminary results presented in this paper were collected three years after planting. The results of yellowish and green seedlings are presented separately. Values represent the average + standard error from eight seedlings from the medium irrigation. The significance of the differences in the shoot fresh weight, root/shoot ratio and photosynthesis was tested by applying the pairwise *t*-test separately at warm, cool and control condition at both sites.

Results and Discussion

There were no differences in the survival of the Scots pine and Norway spruce seedlings. These results are similar to previous findings on the early survival

of planted Scots pine and Norway spruce seedlings on similar sites (POHTILA & POHJOLA 1985). However, the survival of the Scots pine seedlings has decreased drastically 15-20 years after planting (MÄKITALO 1999).

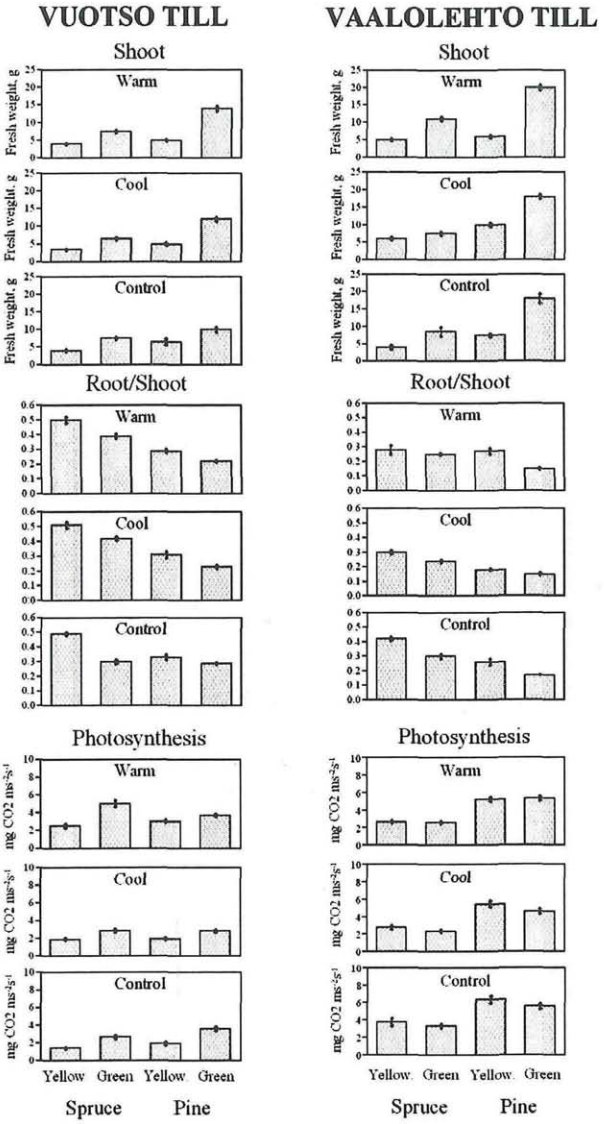

Fig. 1. Biomass development and physiology of Scots pine and Norway spruce seedlings grown in Vuotso on sandy till derived from granite-gneiss bedrock and in Vaalolehto on till derived from chlorite-amphibole schist.. The results are presented separately for yellowish and green seedlings grown in three temperature regimes for three years. The results are the average± S.E. (n=8).

The early development (up to three years) of the Scots pine seedlings was much faster than that of the Norway spruce seedlings. This was seen in the rate of CO_2 fixation (t=15,778-5,934 DF=1,761) and in the accumulation of shoot weight (t=3,359-10,582 DF=1,761) (Fig.1). These results support the previous findings that the productivity of Scots pine seedlings is much higher than that of Norway spruce on these types of till soil (POHTILA & POHJOLA 1985, MÄKITALO 1999).

The root/shoot ratio was typically higher in the Norway spruce seedlings than in the Scots pine seedlings (t=9,354-14,223 DF=1,761). Interestingly, the root/shoot ratio was also high in the Scots pine seedlings that were clearly in poor condition (Fig. 1). The root/shoot ratio in both species and in all the treatments was much higher in Vuotso than in Vaalolehto. These results suggest that the allocation of biomass to the roots is a reaction to the poor growing conditions and not only a species-specific trait of Norway spruce as has been earlier assumed.

High transpiration activity was associated with poor condition of the seedlings (yellowish, data not shown). This was seen especially in Vaalolehto (t=8,806 DF=1,761), where the transpiration of poor pine seedlings was very high in all treatments. The spruce seedlings growing in the sandy till in Vuotso tend to transpire at a higher rate than the pine seedlings.

The early development of the Scots pine seedlings does not support the hypothesis that pines are not able to grow on fine-textured till soils with a high water content. However, the results for the Scots pine seedlings in Vaalolehto indicate that the hypothesis may hold over a longer time-scale. The results for the shoot biomass and root/shoot ratio of the green Scots pine seedlings suggest an imbalance between the shoot as a sink and roots as a source of water and nutrients in later seedling development. Even though the shoots of these seedlings were long, the water potential of the needles was higher (i.e. absorption capacity lower) than that in the yellowish pine seedlings and in the both green and yellowish spruce seedlings. This feature of the green pine seedlings may subsequently result in a shortage of water.

The results of this preliminary study do not support the assumption that Norway spruce seedlings are better adapted to these growing sites. The contradiction between the results of this study and earlier findings with plantations up to 18 years old (MÄKITALO 1999) and adult tress (SUTINEN & al. unpublished) suggest, however, that the monitoring of survival and growth should be continued.

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