Winter in a changing climate affecting the survival of Scots pine seedlings

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Introduction

Climate change scenarios predict increasing precipitation and air temperatures at high latitudes, particularly during autumn, winter and spring. Soil temperatures, however, are more difficult to predict, as they depend on the fate of the insulating snow cover (timing and depth). 'Rain on snow' events and warmer periods in winter can result in thaw-freeze cycles and flooding, and in the formation of ice layers, affecting concentrations of soil gases and microbial activity and the survival of forest tree seedlings.

Materials and Methods

We conducted a laboratory experiment, simulating winter, spring and early summer, and imposed 1.5 year-old Scots pine seedlings to four different winter scenarios:

(1) snow cover
(2) compressed snow and ice encasement (ice)
(3) water-logged and frozen soil (flood)
(4) no snow cover.

During the experiment, we determined needle, stem and root biomass of the seedlings, as well as total soil nutrient concentrations. We also measured the stress that the seedlings experienced by means of chlorophyll fluorescence and gas exchange of the previous-year needles.

Results

The compressed snow and flood treatments significantly affected O_2 and CO_2 concentrations in the soil. The seedlings in the snow and compressed snow treatments survived until the end of the experiment, although only the seedlings in the snow showed normal height growth during spring. The seedlings in the other treatments had almost died at the end of the experiment (dead needles accounted for approx. 80%).

Chlorophyll fluorescence (F_v/F_m) was negatively affected by water-logging or the absence of snow. The photosynthetic apparatus did not recover after the winter treatment without snow. Soil nutrient concentrations did not show any treatment effect, except that of time within the flood treatment, where concentrations of Al, Ca, K, Mg and S were higher after the winter.

Conclusions

The freezing of the water-logged soil seemed to have resulted in mechanical weathering of the mineral soil, and thus in potential leaching of soil base cations, in particular. Our results also suggest the crucial significance of the protective snow cover, and that soil hypoxia during winter and respiratory losses and winter desiccation of aboveground organs were the most probable reasons for the poor condition of the seedlings.

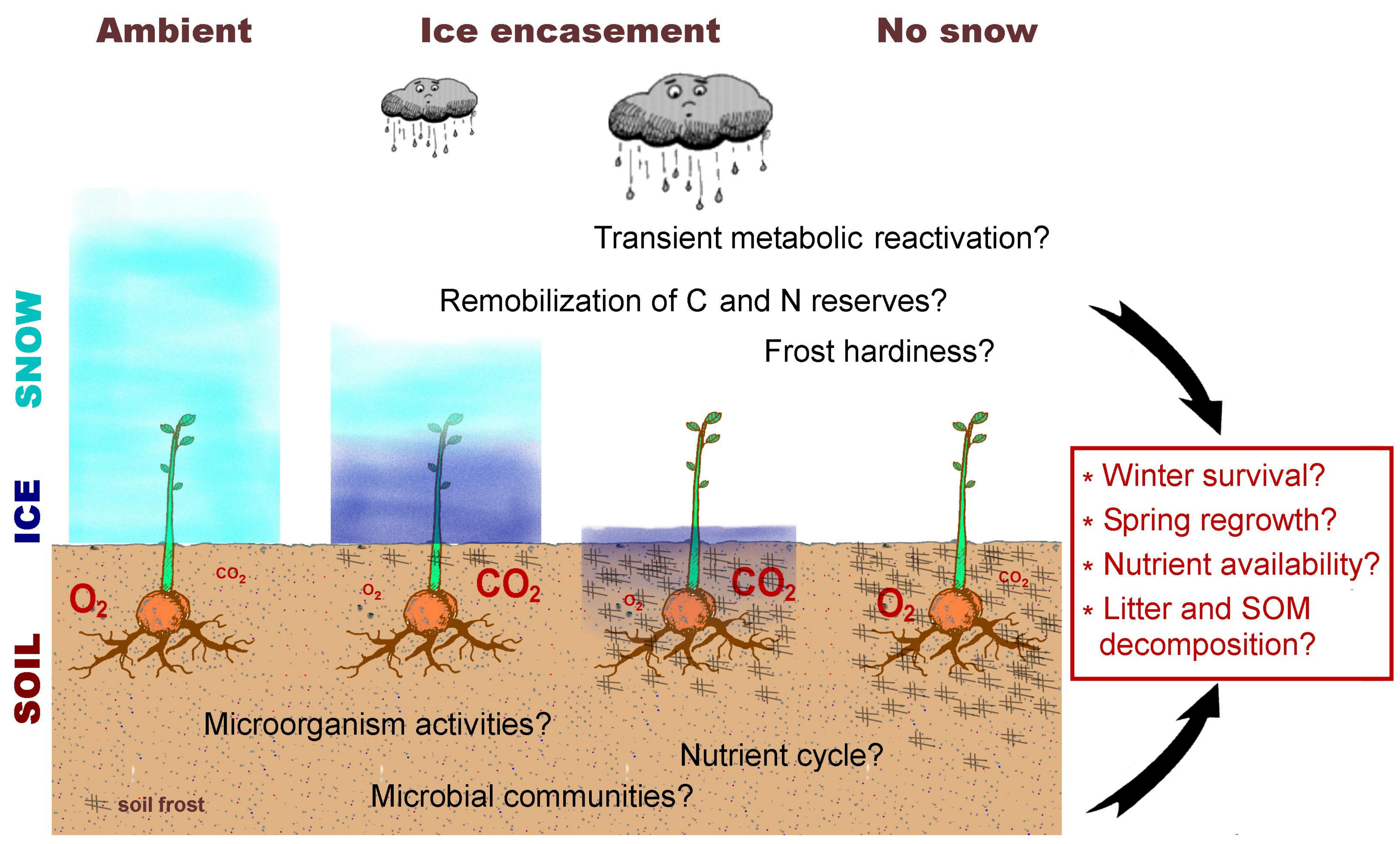

Figure 1. Theoretical framework of the project *

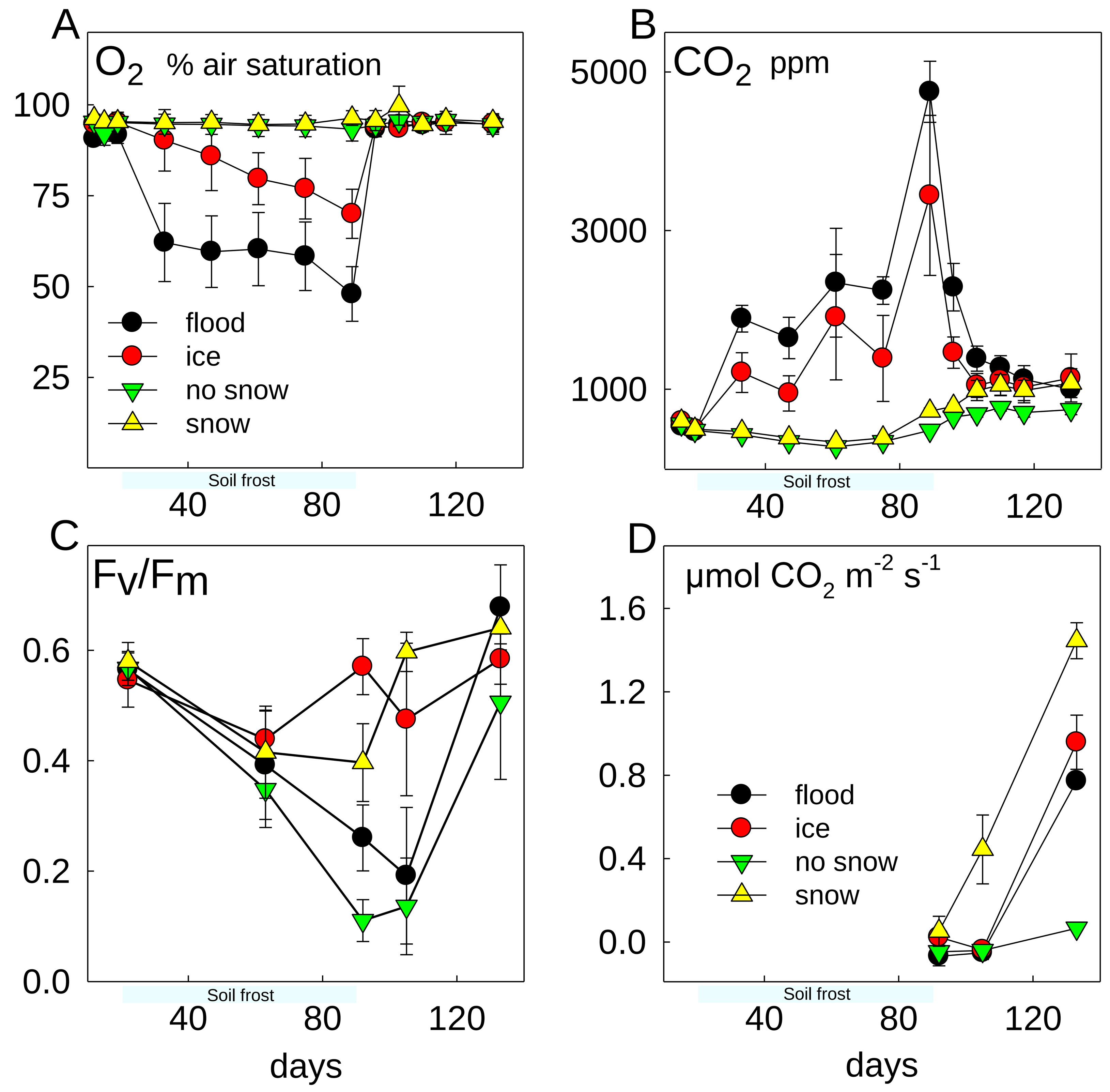

Figure 2. Concentrations of soil (A) O_2 and (B) CO_2 during the experiment. C: Chlorophyll fluorescence: maximum quantum yield of PS II and D: Light saturated net assimilation rate of the previous-year needles after winter (n=4 ±SE). Soil frost indicates the timing of the treatments.

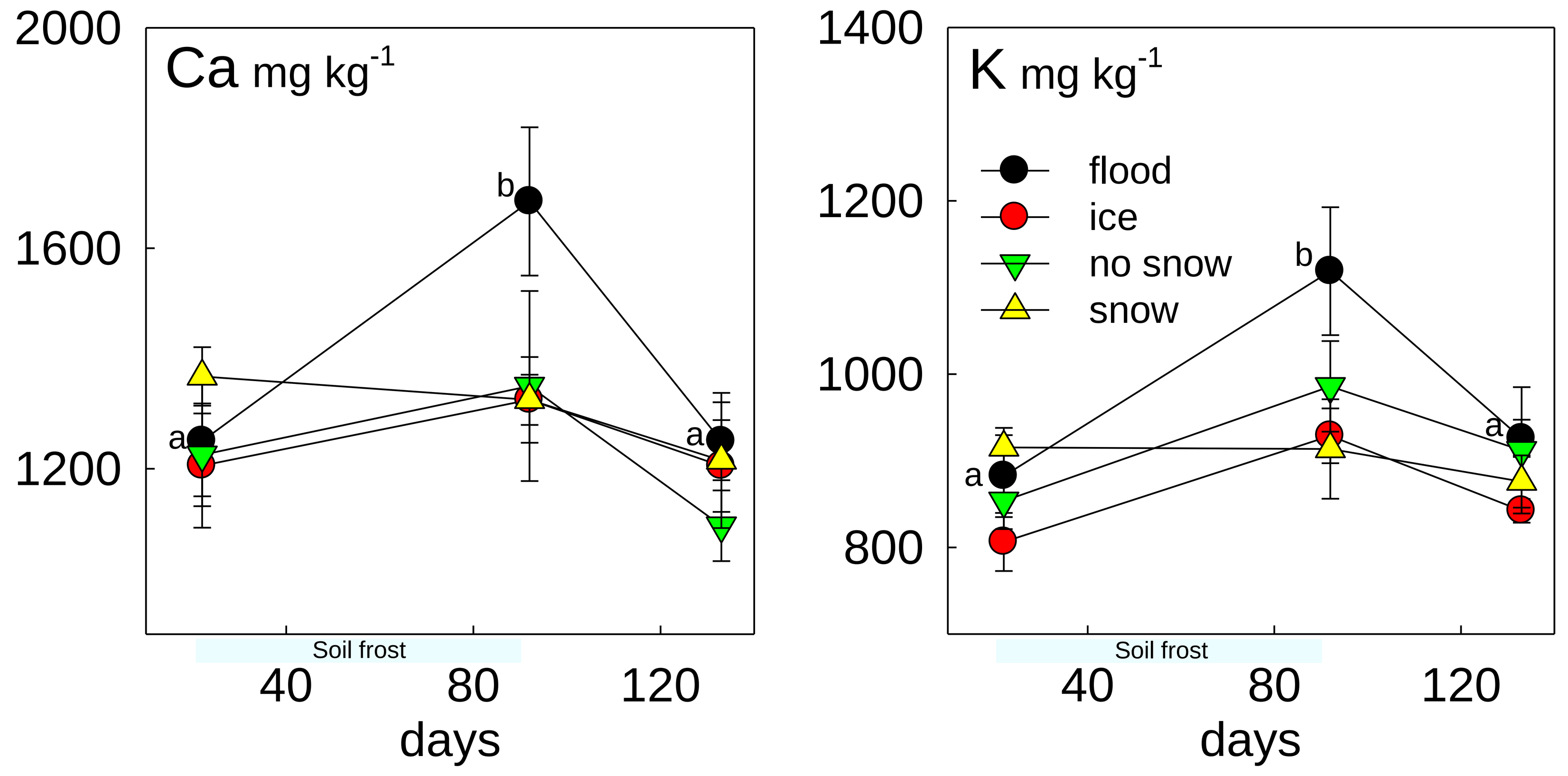

Figure 3. Mineral soil concentrations of Ca and K during the experiment (n=4 ± SE). Different letters indicate statistically significant differences within the water-logged (flood) treatment.

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