Abiotic stress and plant-microbe interactions in Norway spruce

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Abstract

Norway spruce (*Picea abies*) is a dominant tree species in boreal forests with extensive ecological and economic value. Climate change is threatening these ecosystems, with rising temperatures impacting cold hardening and increasing drought stress in regions experiencing lower precipitation. Increasing atmospheric CO_2 concentrations and nitrogen deposition can, in contrast, partially offset such negative effects by improving tree growth and carbon uptake. Similar to aboveground carbon fixation, carbon sequestration in boreal soils is important. Bacteria and fungi mineralize organic matter and, by making nutrients available for plants, are important for tree health. The ability of Norway spruce and the associated microbiota to adapt to climate change is of fundamental importance for ecosystem functioning and is the focus of this thesis. Norway spruce seedlings were subjected to cold or drought stress and the transcriptional response compared to known mechanisms in the model plant *Arabidopsis thaliana*. Analyses revealed that while there was overlap in the stress responses between species, including increased osmotic and oxidative stress tolerance, the majority of differentially expressed genes were stress-responsive only in Norway spruce. Importantly, transcription factors of the abscisic acid dependent and independent pathways were not differentially expressed or were missing homolog sequences in Norway spruce, indicating that different regulatory pathways are active in Norway spruce and suggesting that stress response has evolved differently in the species. Furthermore, differential gene expression in roots differed extensively from that of needles in response to stress and highlighted the need for separate profiling in above- and belowground tissues. In another study at the Flakaliden research site in northern Sweden, the effects of long-term nutrient addition on the microbiota associated with mature Norway spruce were tested. In agreement with earlier findings, nutrient addition improved tree growth and phylogenetic marker gene analysis on DNA of fungi and bacteria provided new insights into associated changes in plant-microbe interactions. Microbial diversity increased over time and compositional changes in nitrophilic community members indicated changes in carbon and nitrogen cycling at the plant-microbe interface, which has implications for carbon storage in boreal forest soils in the future. Follow-up RNA-based techniques largely confirmed community members from marker gene analysis. In summary, understanding of both the Norway spruce-specific responses to abiotic stress and the ability of the associated microbiota to cope with the environmental changes are essential for future productivity, survival and distribution of Norway spruce forests. Sustainability will depend on tree vitality and a more holistic understanding of tree-microbe interactions is required to model future sustainability.

Keywords
Norway spruce, boreal forest, cold, drought, bacteria, fungi, plant-microbe interactions, climate change

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