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Climatic controls of moss-associated nitrogen fixation in the Subarctic

Kathrin Rousk (1,2) and Anders Michelsen (1,2)

(1) Department of Biology, University of Copenhagen, Copenhagen, Denmark (kathrin.rousk@gmx.net), (2) Center for Permafrost (CENPERM), University of Copenhagen, Copenhagen, Denmark

Nitrogen (N_2) fixation performed by moss-associated cyanobacteria is one of the main sources of new N input in pristine, high latitude ecosystems like boreal forests and subarctic tundra. However, N_2 fixation in mosses is strongly influenced by climatic conditions, in particular, moisture and temperature. Previous attempts to temporally scaling up N_2 fixation in mosses from low frequency *in situ* measurements to several weeks, months or even the entire growing season without taking into account changes in abiotic conditions could not capture the variation in moss-associated N_2 fixation. We therefore aimed to estimate moss-associated N_2 fixation throughout the snow-free period in subarctic tundra in field experiments simulating climate change: willow (*Salix myrsinifolia*) and birch (*Betula pubescens* spp. *tortuosa)* litter addition, and warming. The litter additions were sought to simulate shrub expansion in high latitude ecosystems. We established relationships between measured *in situ* N_2 fixation rates and soil moisture and soil temperature and used high-resolution measurements of soil moisture and soil temperature (hourly from May – October) to model N_2 fixation. The modelled N_2 fixation rates were highest in the warmed (2.8 $\pm$0.3 kg N ha^{-1}) and birch litter addition plots (2.8 $\pm$0.2 kg N ha^{-1}), and lowest in the plots receiving willow litter (1.6 $\pm$0.2 kg N ha^{-1}). The control plots had intermediate rates (2.2 $\pm$0.2 kg N ha^{-1}). Our findings suggest that a longer snow-free period and increased temperatures in a future climate will likely lead to higher N_2 fixation rates in mosses. Yet, the consequences of increased litter fall on moss-associated N_2 fixation due to shrub expansion in the Arctic will depend on the shrub species' litter traits.

To follow up on the strong dependence of moss-associated N_2 fixation on moisture and temperature, we collected mosses along a precipitation gradient in subarctic tundra, Northern Sweden and exposed the mosses to different temperature and moisture regimes. We compared N_2 fixation in those mosses to test if the positioning along the gradient resulted in differences in N_2 fixation capability. Nitrogen fixation increased with increasing moss-moisture content and temperature, and the two climatic factors interacted strongly to influence N_2 fixation. The temperature optimum for N_2 fixation was 25 ˚C. Thus, increased temperatures in a future climate will likely lead to an increased N input via the moss-N_2-fixation pathway if mosses are not outcompeted by shrubs expanding into these ecosystems.