Field site description

Soil samples were collected in August 2020 from a dry tundra heath in Abisko (68.19N, 18.50E). The field experiment was established in June 2017, with treatments including (i) control, (ii) chronic litter addition, (iii) chronic N addition, and (iv) combined chronic litter and N addition. Later, in June 2019, two additional treatments were established, including (v) extreme litter addition, and (vi) extreme N addition. For each treatment, 6 replicate plots (1 m × 1 m) were established. For the chronic litter treatment, 90 g m^{-2} birch litter from *Betula pubescens* was added at the beginning of each growth season for four consecutive years. For the chronic N treatment, 5 g N m^{-2} was applied as NH_4Cl at the beginning of each growth season for four consecutive years. For the extreme treatments, three-times the annual additions of N or litter (i.e., 15 g N m^{-2} or 270 g m^{-2} dry birch litter) were added as a single addition in June 2019. 10 L water was added to all plots during the treatment application, to match the water supplied with the inorganic N addition.

Soil sampling and physicochemical analyses

Soil samples were collected from the top 5cm of the organic layer, which had a depth of ca. 5-20 cm. Samples were sieved (< 4 mm) and stored field-moist at 4 °C until analysis. Soil pH and electrical conductivity were measured in water extracts (1:5 w:v soil:water). The moisture content of soils was determined gravimetrically (105 °C for 24 hours), and SOM concentrations were estimated by loss on ignition (550 °C overnight in a muffle furnace).

Laboratory set (Limiting factor assay, LFA)

C, N and P were added to soils in a full factorial design, including: only water addition without any resource as a negative control (“LFA-control”), C addition (“LFA-C”), N addition (“LFA-N”), P addition (“LFA-P”), combined C and N addition (“LFA-CN),

combined C and P addition ("LFA-CP"), combined N and P addition ("LFA-NP"), and combined C, N and P addition as a positive control ("LFA-CNP"), where the lack of a response would suggest that resource other than those supplied could be limiting microbial growth. The LFA-C addition was equivalent to 4 mg C g^{-1} dwt soil, while the LFA-N and LFA-P additions were calculated to achieve a C:N:P mass ratio of 20:1:1. 0.5 g fresh soil was used for each LFA-assay measurement. After the factorial additions, soils were incubated at 18 °C for 24 hours before determining rates of bacterial growth, fungal growth and respiration.

Measurements for microbial growth, respiration and biomass.

Bacterial growth was estimated by ^{3}H-leucine (Leu) incorporation into proteins and ^{3}H thymidine (TdR) incorporation into DNA. Fungal growth was estimated using the ^{14}C-acetate incorporation into ergosterol method. Soil respiration rate (as CO_2 produced by microbes during a certain time) was determined using a gas chromatograph (YL6500 GC, YL Instruments, Gyeonggi-do, Korea). Microbial phospholipid-derived fatty acids (PLFA) were measured to assess responses in microbial biomass to the field treatments. Soils were sampled from the field-experiment sampled in 2019.

Calculation

Total microbial growth was estimated as the sum of bacterial growth and fungal growth. Rates of bacterial growth and fungal growth were first converted to rates of microbial C production. Relative microbial growth was calculated as ((Bacterial growth + Fungal growth)-(mean (Bacterial growth in LFA-control + Fungal growth in LFA-control)))/(mean (Bacterial growth in LFA-control + Fungal growth in LFA-control)), and relative microbial

respiration was calculated as (Respiration – mean (Respiration in LFA-control))/(mean (Respiration in LFA-control)).

The fungal-to-bacterial growth ratio (F:B growth ratio) by dividing fungal growth rates by bacterial growth rates, then log-transforming these data to achieve homogeneity of variance. Microbial substrates use efficiency in the LFA was calculated as (Bacterial growth + Fungal growth) / (Bacterial growth + Fungal growth + Respiration).