

Extended abstract No. 333

EFFECTS OF SIMULATED NITROGEN DEPOSITION ON GROWTH AND CO₂
EXCHANGE CAPACITY OF *SPHAGNUM CAPILLIFOLIUM* AND *POLYTRICHUM*
STRICTUM IN A BOG

Sari Juutinen (Environmental Studies Department, Mount Holyoke College, currently Peatland Ecology Group, Department of Forest Sciences, University of Helsinki, PO Box 27, FI-00014 Helsinki, Finland. Sari.juutinen@helsinki.fi, tel. +358 9 19158147)

Tim Moore, Allison de Young (Department of Geography and Global Environment & Climate Change Centre, McGill University), Anna M. Laine (Peatland Ecology Group, Department of Forest Sciences, University of Helsinki), Margaret Kalacska

Mandy Chong (Department of Geography and Global Environment & Climate Change Centre, McGill University)

Jill L. Bubier (Environmental Studies Department, Mount Holyoke College)

SUMMARY

We studied the responses of height increment and photosynthesis of *Sphagnum capillifolium* and *Polytrichum strictum* to 5 years of elevated N deposition at a bog. Initially, N addition increased the growth rate of both species, but growth of *S. capillifolium* in the high N treatment ultimately decreased to less than the control. *P. strictum* had still slightly higher growth and noticeably increased biomass in the N treatments than in the control in the 5th treatment year. Photosynthesis per ground area responded positively to biomass increase by *P. strictum*.

KEYWORDS: photosynthesis, N deposition, peatland, vegetation, change

INTRODUCTON

The accumulation of organic matter in northern peatlands is primarily associated with slow rates of litter decomposition, especially Sphagna mosses (Moore and Basiliko 2006), and waterlogged soils. Increased deposition of atmospheric nitrogen (N), however, may threaten this accumulation, through decreases in Sphagna growth or increased decomposition. Associated with growth reductions is competition by species benefiting from increased N availability (Gunnarsson and Rydin 2000, Bubier et al. 2007). Vascular plants as well as another common peat moss, *Polytrichum strictum*, have been found to benefit from increased N availability. *Polytrichum strictum* clearly out-competed *S. fallax* in a cutover peatland undergoing restoration (Mitchell et al. 2003). However, another study showed that *P. strictum* can suffer from excess N though it may grow over *Sphagnum* species by being more tolerant (Bu et al. 2010).

In a long-term experiment in Mer Bleue bog (Canada) we have observed a decrease in the coverage of *Sphagnum capillifolium* and an increase in the coverage of *P. strictum*. However, under high levels of N addition (background deposition $\sim 0.8 \text{ g N m}^{-2} \text{ a}^{-1}$ plus 3.2–6.4 g N m^{-2}

a⁻¹) along with phosphorus and potassium addition), shrubs shaded out all the mosses (Bubier et al. 2007, Juutinen et al. 2010). Here we address the effect of simulated N deposition on the growth and the CO₂ exchange capacity of *S. capillifolium* and *P. strictum* in a new field experiment. We measured the annual height increment of these mosses over 5 years. Carbon dioxide (CO₂) exchange rates of the mosses and their N contents were determined in the fifth treatment year. Our hypotheses were: 1) *P. strictum* benefits from the fertilization and N addition increases its growth rate, while N addition decreases growth of *S. capillifolium*. 2) *P. strictum* has higher CO₂ uptake rate than *S. capillifolium* and that it is increased by N addition.

MATERIAL AND METHODS

The research was conducted at the Mer Bleue peatland, near Ottawa, Canada (46°N, 75.5°W). From 1971 to 2000 the mean annual temperature was 6.0°C and the mean annual precipitation was 943 mm, 235 mm of which falls as snow. Background N deposition is ~0.8 g N m⁻² a⁻¹ in the region and fertilization at rates of 0, 3.2 and 6.4 g N m⁻² a⁻¹ was applied to triplicate 3 × 3 m plots per treatment, in dissolved form as NH₄NO₃ in seven 2-mm waterings from May to August 2005-2009. These treatments are called 0N (control), 3.2N and 6.4N.

Moss growth was measured by the cranked wire method (Clymo 1970). Plastic-covered, 2-mm diameter metal rods were inserted into the peat surface and the distance between the tips of the rod and the surrounding *S. capillifolium* and *P. strictum* was measured in early April and late October from 2005 to 2009, to capture most of the growing season. There were 10 replicate rods in each plot.

Moss cores for the CO₂ exchange measurements were sampled on October, 2009, after 5 years of fertilization. Two cores (diameter 7.2 cm, top 2 cm of the *Sphagnum* stems with capitulum) were sampled from each plot. In each sample both species were present. One core was kept intact, and only vascular plants and visible detritus were removed. Species in the other core were separated: *P. strictum* were removed from the *Sphagnum* sample and then planted on quartz sand. Samples in plastic pots (diameter 7.2 cm, height 3 cm) were watered with distilled water and placed into a growth chamber. Conditions were set as follows: 16 h light, photosynthetically active photon flux density (PPFD) ~ 250 μmol m⁻² s⁻¹ at the moss surface, 8 h darkness, temperature: 18°C day and 10°C night, CO₂ concentration 380 ppm, and humidity 70%.

Each sample pot was measured for CO₂ exchange under three moisture contents and under light levels of about 700, 500, 250, 150 PPFD μmol m⁻² s⁻¹ and in the dark. Measurements were made by using a small chamber (10 cm diameter, 10 cm high). Headspace CO₂ concentrations were recorded every 15 s over a ~3 min period using an EGM4 (PP-Systems, MA, USA) infrared gas analyzer. PPFD under the chamber, temperature and sample weight were determined for each measurement. Gravimetric moss water contents were calculated at the end of the experiment. The CO₂ exchange rate was calculated from changes in CO₂ concentrations, gas chamber volume, and temperature checking for leaks. Gross photosynthesis at each light level was estimated by summing net CO₂ exchange and the dark respiration. Here we present only results of gross photosynthesis under optimal conditions (WC ~1000–2000%, PPFD ≥600). Upon completion of the experiment, the moss samples

were oven dried (60°C) to determine dry biomass. Sub samples were ground and analyzed for C and N concentrations using a Carlo ErbaTM Elemental Analyzer, model NC2500.

RESULTS

Cumulative growth of *S. capillifolium* from mid April 2005 to late October 2009 was highest in 0N and 3.2N treatments. In turn, the cumulative growth of *P. strictum* was highest in the 3.2N and 6.4N treatments where it was 1.5 times the growth in the 0N treatment. *S. capillifolium* showed a slight growth increase as response to N addition in the second and third year (Fig. 1). After that, height growth, on the average, declined in the N addition treatments, with dramatic decline under the 6.4N treatment. *P. strictum* showed a stronger growth increase than *S. capillifolium* under both N addition treatments. Growth increase was largest in the second year, but the difference between treatments and the control decreased in the fifth year.

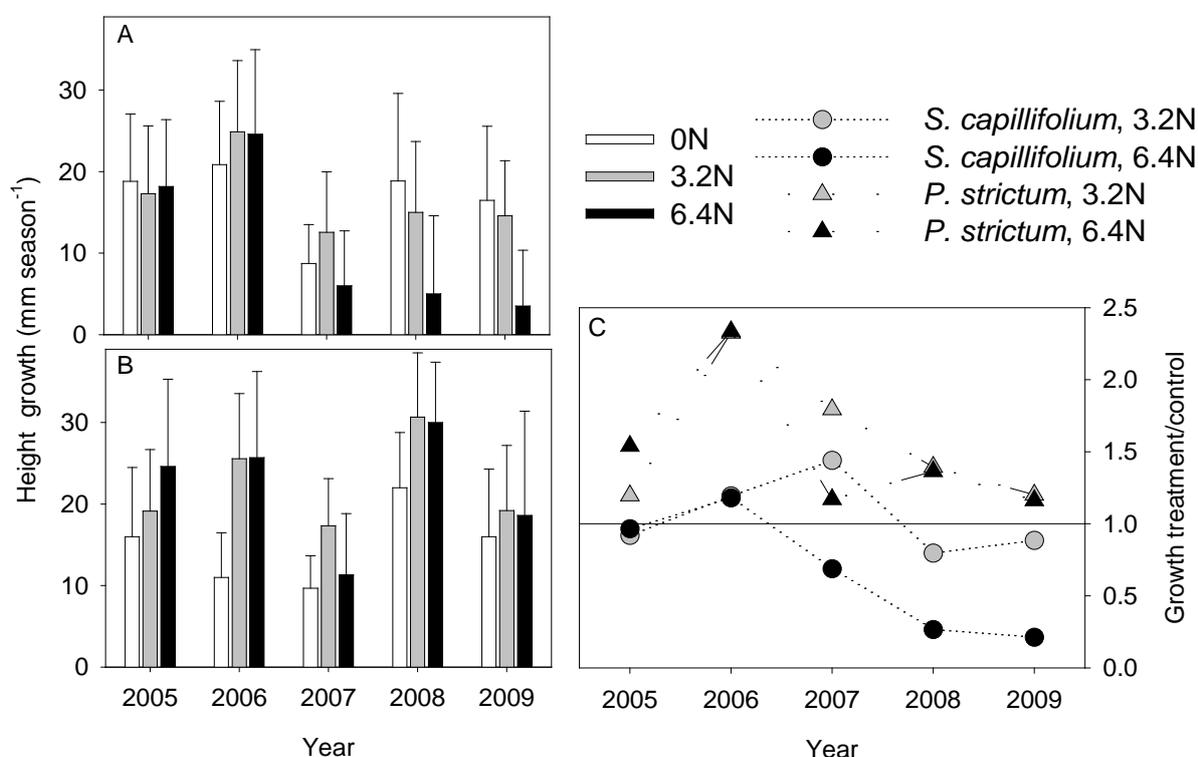


Fig. 1. Mean annual height growth rates (\pm SD) of A) *S. capillifolium* and B) *P. strictum* in the treatments from year 2005 to 2009, and C) height growth in the treatments relative to the control.

The concentration of N in *S. capillifolium* capitula and *P. strictum* averaged 0.71 and 0.86%, respectively, in the 0N treatment. The 3.2N and 6.4N treatments increased N concentration in *S. capillifolium* (to 1.19% and 1.42%) more than in *P. strictum* shoots (to 1.06% and 1.25%). The biomass of *S. capillifolium* samples was nearly similar in all treatments but *P. strictum* biomass increased to three and four fold in the 3.2N and 6.4N treatments, respectively.

Mean light saturated gross photosynthesis rate per unit ground area increased by a factor of 1.5 from 0N to 6.4N in the intact moss cores (Fig. 2A). The 6.4N treatment decreased photosynthesis of the *Sphagnum*. In turn, *P. strictum* cores had 6 times higher mean photosynthesis rate in the 6.4N treatment than in the 0N treatment. The differences between treatments in the intact cores and *P. strictum* cores disappeared when the photosynthesis rate was expressed per unit moss biomass (Fig. 2B). It seemed that *S. capillifolium* still had smallest photosynthesis rate under the 6.4N treatment.

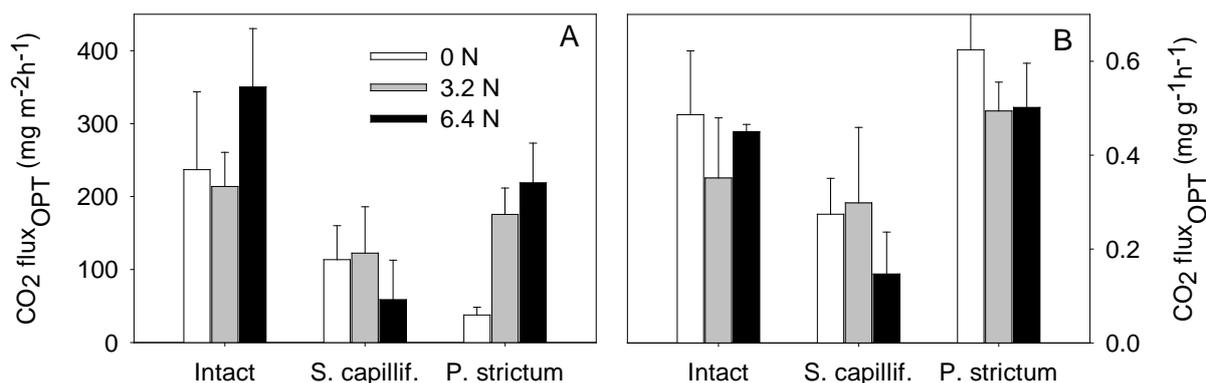


Fig. 2. Light saturated gross photosynthesis A) on area basis ($\text{mg m}^{-2} \text{h}^{-1}$) and B) on mass basis ($\text{mg g}^{-1} \text{h}^{-1}$). Bars show treatment means error bars denoting standard deviation ($n = 3$) in cores having intact moss vegetation, *S. capillifolium* only, and *P. strictum* in quartz sand.

DISCUSSION

The N addition rates in this study greatly exceeds the background N deposition at the site and in northern Europe, but reach the highest depositions in the central Europe (e.g. Solberg et al. 2009). These, or even higher, addition levels are common in the experiments (e.g. Gunnarsson and Rydin 2000).

The initial increase in height increment indicated that both species were originally N limited, but the situation soon changed. Also the lower N addition level caused a growth reduction in *S. capillifolium* after the third year. This result agrees with a study by Gunnarsson and Rydin (2000), which suggested that even low, $<1 \text{ g N m}^{-2} \text{ a}^{-1}$, deposition rates can saturate *Sphagnum* mosses in a few years leading to growth reduction. *P. strictum* is more tolerant, but it seems that its growth also returns to the control or lower level. However, in this experiment N addition did not decrease *P. strictum* growth as it did in the study of Bu et al. (2011). The stronger growth of *P. strictum* compared to *S. capillifolium* possibly restricted the increase of the N concentration in the shoot and thus slowed the crossing of critical N/P quotient, which is a possible mechanism for growth reductions (cf. Gunnarsson and Rydin 2000, Granath et al. 2011).

In this study the photosynthetic capacity per unit mass of *P. strictum* and *S. capillifolium* remained unchanged or was reduced by N addition regardless of increased shoot N concentration. In turn, Granath et al. (in press) suggested that N deposition increases photosynthetic capacity owing to increase in cellular N concentration but that P limitation

restricts biomass production. Over the time span of this study, *P. strictum* has competed efficiently with *S. capillifolium* under increased N supply, and by increasing biomass this can enhance the photosynthesis of the moss layer. This differs from the N + phosphorus and potassium fertilization experiment, where nearly all *P. strictum* was killed under the 6.4N load in five years (Bubier et al. 2007), suggesting that phosphorus limitation restricts the vascular plant growth.

REFERENCES

- Bu, Z.J., Rydin, H., and Chen, X. (2011). Direct and interaction-mediated effects of environmental changes on peatland bryophytes. *Oecologia* **166**, 555–563.
- Bubier, J.L., Moore, T.R., Bledzki, L. (2007). Effects of nutrient addition on vegetation and carbon cycling in an ombrotrophic bog. *Global Change Biology* **13**, 1168-1186.
- Clymo, R.S. (1970). The growth of *Sphagnum*: methods of measurement. *Journal of Ecology* **58**, 13–49.
- Granath, G., Strengbom, J., and Rydin, H. (in press). Direct physiological effects of nitrogen on *Sphagnum*: a greenhouse experiment. *Functional Ecology*, doi :10.1111/j.1365-2435.2011.01948.x.
- Gunnarsson, U. and Rydin, H. (2000). Nitrogen fertilisation reduces *Sphagnum* production in Swedish bogs. *New Phytologist* **147**, 527–537.
- Juutinen, S. J. Bubier, T. Moore. 2010. Responses of vegetation and ecosystem CO₂ exchange to 9 years of nutrient addition at Mer Bleue bog. *Ecosystems* **13**:874-887, DOI:10.1007/s10021-010-9361-2.
- Mitchell, E.A.D., Buttler, A., Grosvenier, P., Rydin, H., Siegenthaler, A., and J-M Gobat (2002). Contrasted effects of increased N and CO₂ supply on two keystone species in peatland restoration and implications for global change. *Journal of Ecology* **90**, 529–533.
- Moore, T. and Basiliko, N. (2006). Decomposition. In Wieder, R.K. and Vitt, D.H. (eds.) *Boreal Peatland Ecosystems. Ecological Studies* **188**, 126-143. Springer-Verlag.
- Solberg, S., Dobbertin, M., Reinds, G.J., Lange, H., Andreassen, K., Fernandez, P.G., Hildingsson, A., and de Vries, W. (2009). Analyses of the impact of changes in atmospheric deposition and climate on forest growth in European monitoring plots: A stand growth approach. *Forest Ecology and Management* **25**, 1735–1750.