# Scaling plant nitrogen-use and uptake efficiencies in response to nutrient addition in peatlands

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## Introduction

- Plant production per unit N taken up (N use efficiency, NUE) is an index of ecosystem function in nutrient-limited ecosystems (Aerts and Chapin 2000).
- NUE comprises two conflicting processes: N-productivity ($A_N$, plant production per peak biomass N content) and the mean residence time of N in plant biomass ($MRT_N$) (Berendse and Aerts, 1987).
- Plant adaptation and response to nutrient gradients may be better understood by measuring plant N uptake or production per unit of N available in the soil (N uptake efficiency and N response efficiency, respectively, cf. Pastor and Bridgham 1999).
- Our objectives were to determine how the addition of N, phosphorus (P), or a combination of N and P to a gradient of nutrient-limited peatland ecosystems would affect: (i) the adaptive tradeoff between the components of NUE; (ii) plant N acquisition from the soil (N uptake efficiency); and (iii) plant production per unit soil N availability (N response efficiency).

## Methods

We fertilized 32 × 32 m plots in a bog, an intermediate fen, and a rich fen (see below) in the Upper Peninsula of Michigan, USA with 6 g $N \cdot m^{-2} \cdot yr^{-1}$, 2 g $P \cdot m^{-2} \cdot yr^{-1}$, or a combination of N and P from 1998 to 2002. In 2002, we measured the production and N content of up to 98% of the vascular plant community.

| BOG | INTERMEDIATE FEN | RICH FEN |
|---|---|---|
| | | |
| pH = 3.8 | pH = 4.9 | pH = 6.0 |

## Results

Data in figures are treatment or site means ± 1 SE (aboveground processes are shaded with blue, belowground processes with white). Letters signify significant differences among sites before nutrient addition ($P < 0.1$). †$P < 0.10$; *$P < 0.05$; **$P < 0.01$ and ***$P < 0.001$.

## Discussion

- NUE generally declined in response to nutrient addition as would be expected. However, the addition of a limiting nutrient tended to decrease $A_N$ and, conversely, increase $MRT_N$. This lead to muted changes in NUE, both above- and belowground (Fig. 2). This may make it difficult to predict ecosystem responses to nutrient availability using the NUE index.
- In contrast to NUE, greater N availability led to large declines in N uptake efficiency (Fig. 3). Surprisingly, N uptake efficiency increased in response to greater P availability (Fig. 3). Decreased relative N uptake with N addition could mean greater N losses from the system as a whole, while on the other hand, P addition may increase the ability of plants to acquire N from the soil.
- The similarity in N uptake efficiency and N response efficiency between the above- and belowground components of the plant communities (Fig. 3) could indicate a direct link between nutrient uptake by roots and plant production.
- Phosphorus availability had large effects on plant production and N uptake in all three peatlands, and may exert strong controls over plant N use across nutrient availability gradients.
- Altered plant nutrient acquisition and production in response to increased nutrient availability in peatlands could affect the delicate balance between production and decomposition that leads to C accumulation in peatland ecosystems.

## Literature cited

Adapted from: Iversen CM, Bridgham SD, Kellogg SE. *In press*. Scaling plant nitrogen-use and uptake efficiencies in response to nutrient addition in peatlands. *Ecology*.

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Pastor, J. and S. D. Bridgham. (1999) Nutrient efficiency along nutrient availability gradients. *Oecologia* 118: 50-58.

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Figure 1

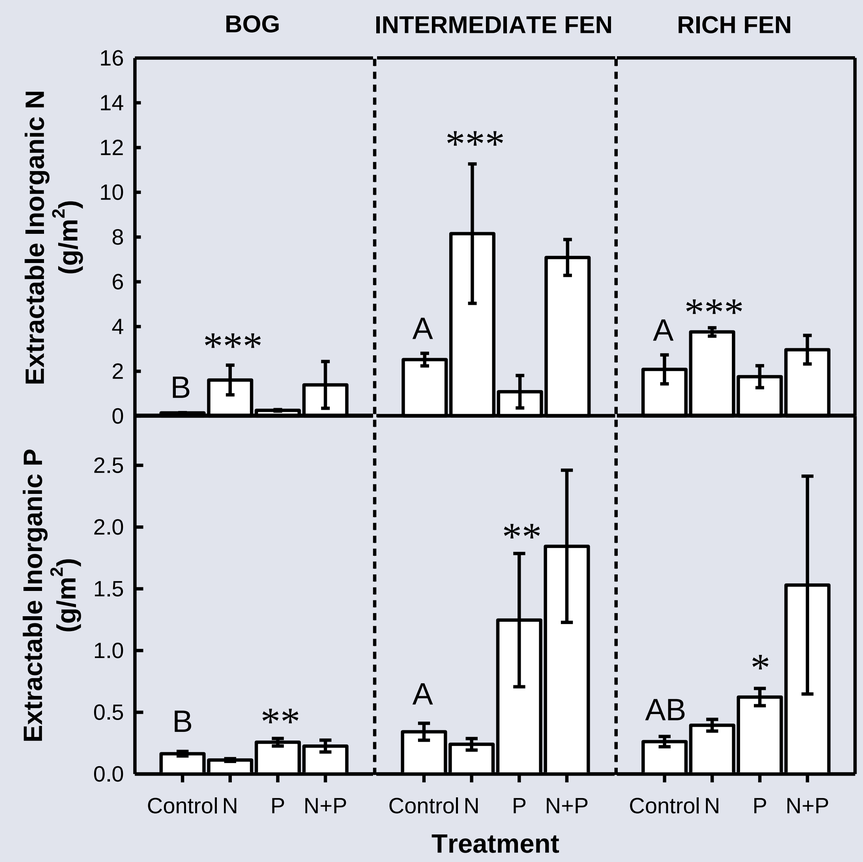


**Fig. 1** Before nutrient addition, nutrient availability was generally least in the bog and greatest in the fens. Fertilization with N, P, or a combination of nutrients, increased N or P availability within a site to 25-cm depth. There were no interactions between N and P.

Figure 2

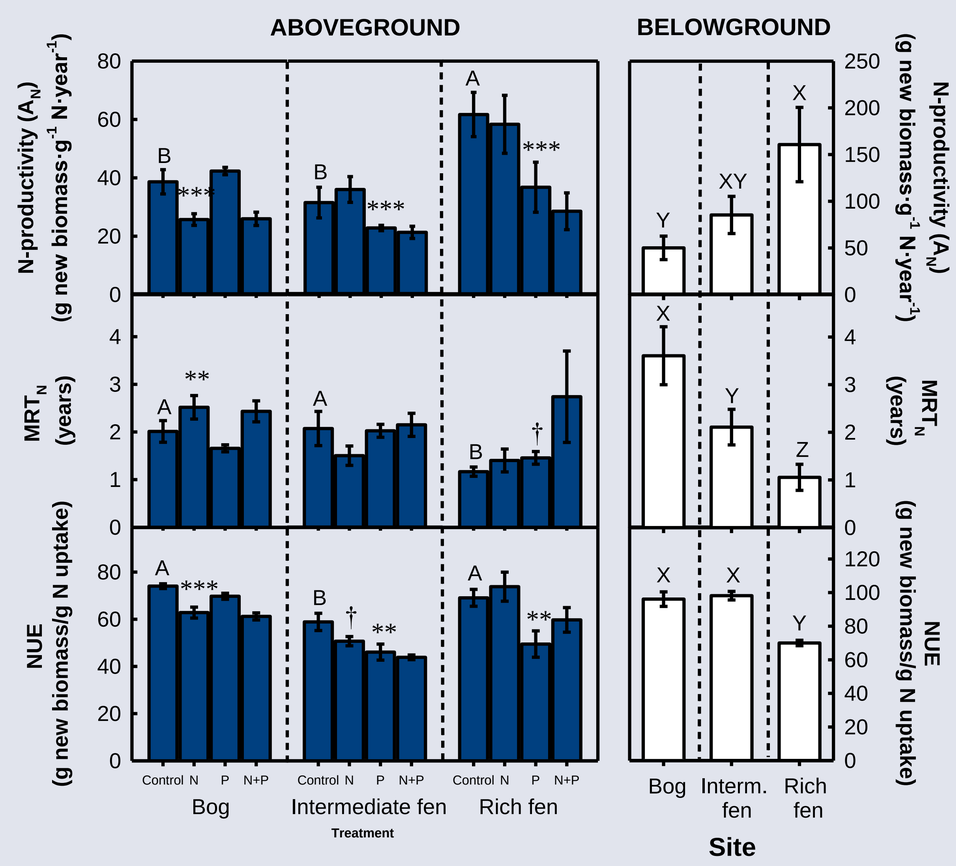


**Fig. 2** Above- and belowground community N productivity ($A_N$) and the mean residence time of N ($MRT_N$) often differed in the directionality of their response to increased nutrient availability within and among sites. Thus, changes in NUE were dampened ($A_N \times MRT_N$ = NUE).

Figure 3

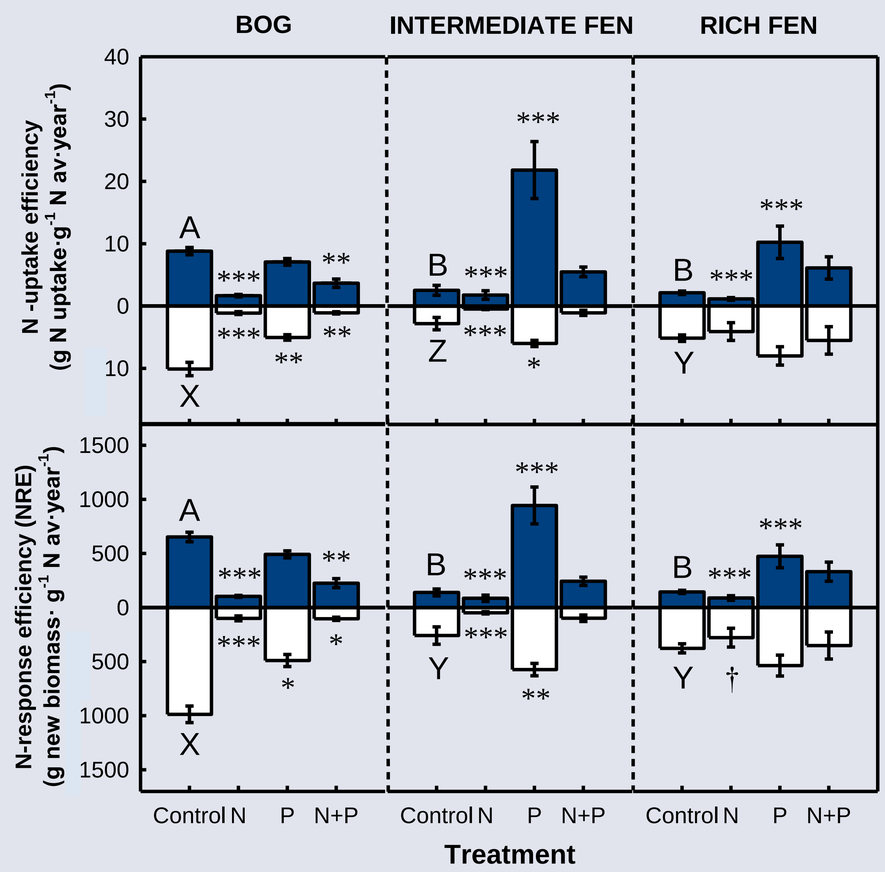


**Fig. 3** N availability decreased, and P availability increased, above- and belowground N uptake efficiency and N response efficiency. Above- and belowground efficiencies (above and below the line, respectively) responded to nutrient addition in a similar manner.