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

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Abstract. Nitrogen (N) is the primary growth-limiting nutrient in many terrestrial ecosystems, and therefore plant production per unit N taken up (i.e., N use efficiency, NUE) is a fundamentally important component of ecosystem function. Nitrogen use efficiency comprises two components: N productivity (A_N, plant production per peak biomass N content) and the mean residence time of N in plant biomass (MRT_N). We utilized a five-year fertilization experiment to examine the manner in which increases in N and phosphorus (P) availability affected plant NUE at multiple biological scales (i.e., from leaf to community level). We fertilized a natural gradient of nutrient-limited peatland ecosystems 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. Our objectives were to determine how changes in carbon and N allocation within a plant to leaf and woody tissue and changes in species composition within a community, both above- and belowground, would affect (1) NUE; (2) the adaptive trade-off between the components of NUE; (3) the efficiency with which plants acquired N from the soil (N uptake efficiency); and (4) plant community production per unit soil N availability (N response efficiency, NRE). As expected, N and P addition generally increased aboveground production and N uptake. In particular, P availability strongly affected the way in which plants took up and used N. Nitrogen use efficiency response to nutrient addition was not straightforward. Nitrogen use efficiency differed between leaf and woody tissue, among species, and across the ombrotrophic–minerotrophic gradient because plants and communities were adapted to maximize either A_N or MRT_N, but not both concurrently. Increased N availability strongly decreased plant and community N uptake efficiency, while increased P availability increased N uptake efficiency, particularly in a nitrogen-fixing shrub. Nitrogen uptake efficiency was more important in controlling overall plant community response to soil N availability than was NUE, and above- and belowground community N uptake efficiencies responded to nutrient addition in a similar manner. Our results demonstrate that plants respond to nutrient availability at multiple biological scales, and we suggest that N uptake efficiency may be a more representative measurement of plant responses to nutrient availability gradients than plant NUE.

Key words: allocation; co-limitation; mean residence time; N limitation; nitrogen response efficiency; nitrogen uptake efficiency; nitrogen use efficiency; nutrient productivity; peatlands; P limitation; Upper Peninsula, Michigan, USA.