Foliar Analysis of Six Northern Hardwood Species Indicates Nutrient Limitation

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Introduction

- Foliar nutrient concentrations are good indicators of plant nutrient status and relative nutrient limitation.
- Increases in atmospheric nitrogen (N) deposition have affected the biogeochemistry of forests through changes in pH, net nitrification, and nutrient limitation status.
- On a global scale, limitation by N or phosphorus (P) may be driven by geologic history and soil type where highly weathered trophic soils are likely to be more P-limited and recently glaciated temperate soils are likely to be N-limited.
- The Multiple Element Limitation in Northern Hardwood Ecosystems (MELNHE) project was established to study N and P acquisition and limitation through a series of nutrient manipulations in northern hardwood forests.

Objectives

- Determine the effects of nutrient additions (N, P, and N+P) on foliar nutrient status of six northern hardwood species.

Site Description

- Ten stands, located in HBEF, BEF and Jeffers Brook of NH, have primarily well-drained acid Spodosols (Haplorthods) of sandy loam texture developed from glacial till. The climate is humid continental, with an annual temperature and precipitation averaging 5.7°C and 1400mm at HBEF and 4.4°C and 1300 mm at BEF (Fig 1).
- Overstory vegetation is dominated by American beech, sugar maple, white birch and yellow birch, which altogether accounts for 70% of the forest basal area at HBEF, 55% at BEF, and 63% at Jeffers Brook.
- N (30 kg N/ha/yr as NH_4NO_3), P (10 kg P/ha/yr as NaH_2PO_4), and N+P (same amount) were applied annually to plots beginning in spring 2011.

Sampling Method

- Green leaves of American beech (*Fagus grandifolia*), pin cherry (*Prunus pensylvanica*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), white birch (*Betula papyrifera*) and yellow birch (*B. alleghaniensis*) were collected at the end of the growing season between 2014 and 2016.
- All leaf samples were oven-dried at 60°C to constant mass and ground using a Wiley mill before passing through a 60-mesh screen.

Chemical Analyses

- Foliar N concentrations were determined with a FlashEA 1112 analyzer (Thermo Scientific). Foliar P concentrations were determined with an Optima 5300 DV ICP-OES (Perkin-Elmer) after samples were ashed and hot plate-digested with 6N nitric acid.

Data Analysis

- To test for NxP factorial treatment effects, a linear mixed-effects model and analysis of variance (ANOVA) was performed along with Species, Age, and Site, where Stand nested within Age and Site was considered a random effect. All statistical analysis and graphs were done using lme4 and ggplot packages in R (v. 1.1.463).

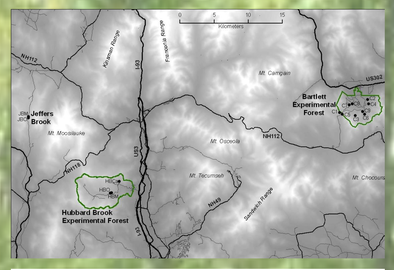
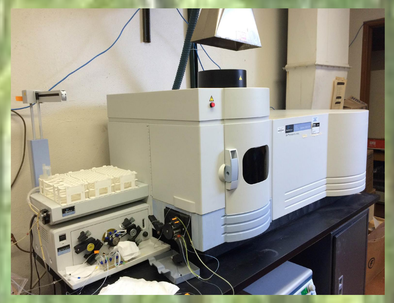


Fig 1. Map of the 10 stands in HBEF, BEF and Jeffers Brook.



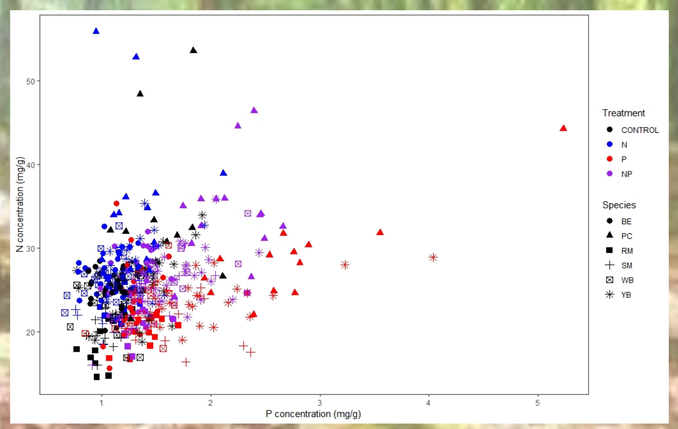


Fig 2. Foliar N was higher under N-addition ($p<0.001$) and lower under P-addition ($p<0.05$). Mid-age stands were higher than mature stands ($p<0.01$). Foliar P was higher under P-addition ($p<0.001$) and lower under N-addition ($p<0.01$). Young stands reported the lowest ($p<0.01$). For both foliar N and P, species varied ($p<0.001$) with PC reporting the highest and BE the lowest. There was an N and P interaction ($p=0.05$), N and species ($p<0.001$) and P and species ($p<0.001$) interactions.

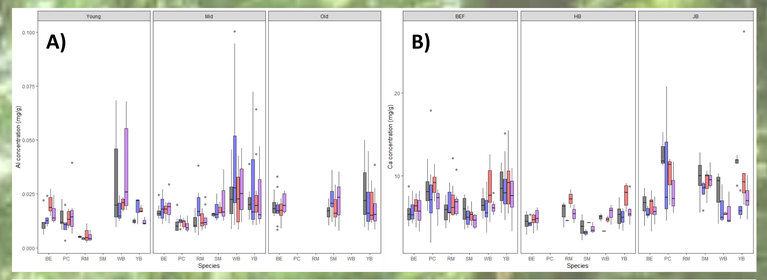


Fig 3. **A)** Foliar Al was higher under N-addition ($p=0.08$) but foliar Ca was lower under N addition ($p<0.01$). Birches reported the highest foliar Al ($p<0.001$), followed by PC and RM; but there was no significant difference between PC and RM. **B)** PC reported the highest foliar Ca ($p<0.001$), followed by the YB, WB and RM. Young stands reported the lowest foliar Al ($p<0.01$) and BEF reported the highest foliar Al ($p<0.001$). JB reported the highest foliar Ca ($p<0.001$), followed by HB and BEF; young stands reported the highest foliar Ca ($p<0.03$). There was an N and species interaction for foliar Ca ($p=0.051$).

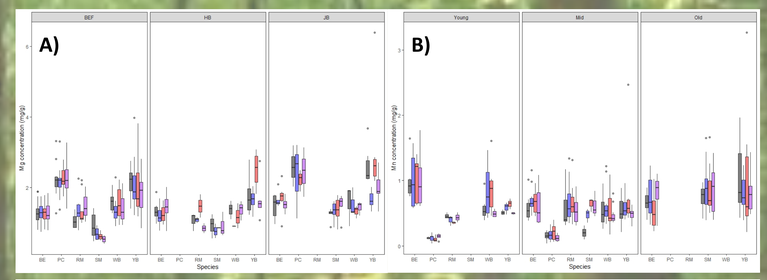


Fig 4. **A)** Foliar Mg varied by species ($p<0.001$) with PC being the highest, followed by the birches and maples; young stands ($p<0.01$) and JB ($p<0.001$) reported the highest foliar Mg. There was a N and species interaction ($p<0.01$). **B)** Foliar Mn varied by species ($p<0.001$) with PC reporting the lowest and mid-aged stands reported the lowest ($p<0.01$). There was a N and species interaction ($p=0.09$).

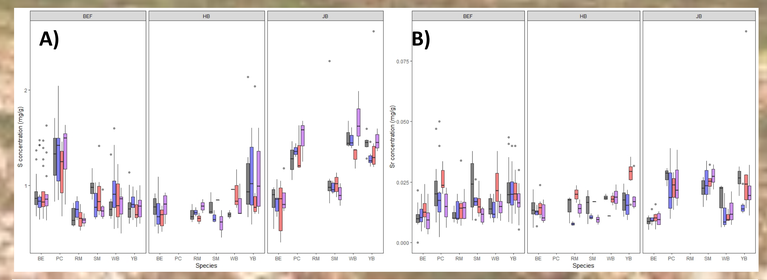


Fig. 5. **A)** Foliar Sr was higher under N-addition ($p<0.01$) and varied by species ($p<0.001$) with PC reporting the highest and BE the lowest. There was a N and species interaction ($p<0.1$). **B)** Foliar S varied by species ($p<0.001$) with PC reporting the highest and JB reported the highest ($p<0.001$). There was a N and species interaction ($p=0.06$).

Discussion

- Foliar N and P were higher with additions of the respective nutrient, as expected. However, foliar N and P were lower with additions of the other nutrient, which may reflect vegetative growth or microbial immobilization.
- Foliar Al was higher with N addition which may be attributed to the reduced pH by N permitting the mobilization of toxic Al and Mn ions.
- Foliar Ca was lower with N addition because hydrogen ions are exchanged into the soil solution from reduced pH and displace the base cations (Ca and Mg) adsorbed to soil exchange sites.

Conclusions

- Temperate forest on glaciated soils are generally thought to be N-limited, but long-term NxP manipulations in this biome are lacking. Our results suggest that decades of anthropogenic N deposition may have tipped the balance to P limitation in these forests (Goswami, 2018).