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Soil lichen influence on nitrogen cycling in the soils of the NJ Pinelands

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Lichen Mediation of Soil Responses to Nitrogen Deposition

N addition may be a principal driver of ecosystem change in temperate and boreal forest and grassland landscapes (Magnani et al. 2007). Excess N can have widespread impacts through the effects on the soils; ammonium deposition can lead to soil acidification, base cation depletion, and solubilization of toxic metals. N deposition can also lead to N leaching in watercourses and eutrophication.

Studies in the NJ Pinelands have found that nitrogen deposition changes abundance and diversity of ectomycorrhizae (Dighton et al. 2004); we were interested in discovering how lichens mediate the soil response to nitrogen deposition when nitrogen deposition occurs over lichen mats. We added N-15 enriched NH_4NO_3 monthly to small plots, collecting runoff water periodically, and harvested soils and lichens at the end of the season. This allowed us to measure N uptake in the growing and senescent parts of the lichens, allowing us to compare lichen N use in temperate forests with similar studies in boreal lichens (Hogan et al. 2010)).

Hypotheses and Experimental Design

Our hypothesis was that lichens would use the excess nitrogen, especially in growing tips, so would depress N concentrations in soil and groundwater below. At extremely high N loads, the N use in the lichens would not be able to protect the of in soil and groundwater from excess N.

N treatment. We added ammonium nitrate to the mesocosms at 3 different treatment concentrations:

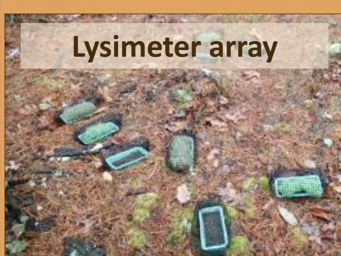
- 0 kg N $ha^{-1}yr^{-1}$ (no excess nitrogen)
- 5 kg N $ha^{-1}yr^{-1}$ (low N deposition)
- 50 kg N $ha^{-1}yr^{-1}$ (high N deposition)

Aboveground treatments. We were interested in whether the biological activity or physical structure of the lichens was important in N cycling. We compared effects of 3 different aboveground treatments:

- Bare (no soil cover)
- False lichen (fabric) made of polyester mesh
- Lichen: *Cladonia subtenuis*, a common lichen at these sites

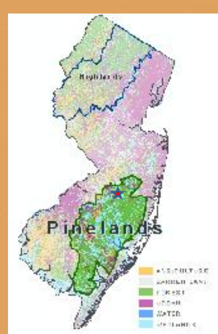
We arranged the lichen, false lichen, or control plot, in lysimeters, plastic trays with a drainage hole at the bottom, and collected leachate in 2L Nalgene bottles below the trays.

Isotopic Enrichment: using 10% N-15 labelled NH_4NO_3, we were able to trace where the nitrogen from these additions goes. If there is no difference in N accumulation with high levels of N deposition, we can assume that the lichens are N-saturated.



STUDY SITE

Lysimeter arrays were set up outdoors in open canopy areas from June-November 2014 at Rutgers Pinelands Research Station, New Lisbon, NJ



RESULTS: Changes to soils

The soils with lichens on top retained moisture better than the other treatments (Fig 1). But total leaching to groundwater over the season was the same for lichens and fabric (Fig 2), suggesting that the lichen effect on soil moisture was mainly due to shading and not actually to fungal retention of water. Lichens leached slightly less N to water (Fig 3)

Lichens slightly reduced NH_4^+ concentrations in soils below them (Fig 5) when low levels of N were added, but lichens let about twice as much NH_4^+ accumulate below them with high N additions, and lichen effects were not significantly different from the effects of fabric. Lichens also slightly increased organic N concentrations in soils below them (Fig 4), but the effect was also not significantly different from the effects of fabric. The fabric-lichen functional equivalence suggests that the physical structure of the lichens may regulate the interaction with N, for example by increasing atmospheric nitrogen absorption by providing habitat for microbes.

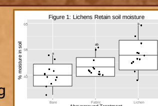


Figure 1: Lichens Retain soil moisture

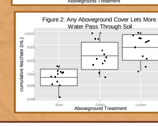


Figure 2: Any Aboveground Cover Lets More Water Pass Through Soil

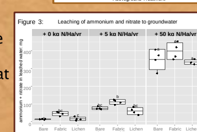


Figure 3: Leaching of ammonium and nitrate to groundwater

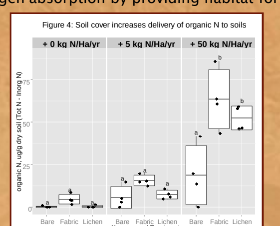


Figure 4: Soil cover increases delivery of organic N to soils

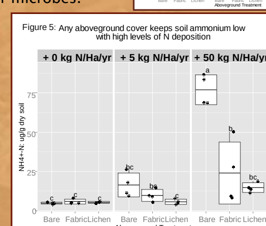


Figure 5: Any aboveground cover keeps soil ammonium low with high levels of N deposition

RESULTS: Nitrogen Enrichment

We calculated N enrichment using the formula for relative N uptake (Dahlman et al, 2002)

Relative N uptake = $[(15N_s - 15N_c) \times (totN/.1)]$, where:

- $15N_s$ is the %15N of the sample ,
- $15N_c$ is the %15N in the control (no extra 15N added
- totN is the total N concentration (sum of $^{15}N$and ^{14}N in $g/g_{dry\ wt}$),
- .1 corrects for the fraction of labeled N in the N additions

We found that the growing tips of the lichens took up the N-15 from the additions, more than did the bases of the lichens (Fig 6); negligible N was adsorbed to the fabric or incorporated in microbes on the fabric. With 10x increase in of N-15 additions, the lichens were only able to incorporate about 3x the quantities of N-15.

About twice as much added N was incorporated in the soil in high N deposition conditions (Fig 7). These patterns suggest that lichens can still maintain low soil N levels when less than 5 kg N $ha^{-1}yr^{-1}$ is added, but more N can overwhelm the capacity of lichens to capture or use the N, and the soil N levels increase (Fig 7). Some absorptive capacity of the lichen and fabric seems to be exceeded between 5 and 50 kg N $ha^{-1}yr^{-1}$.

These findings make sense in the context of lichen physiology. Ammonium can be held in cation exchange sites in the extracellular space of the thallus; those ammonium ions are easily lost the environment (Miller and Brown 1999). Some of the N can be assimilated but other physiological conditions (like P limitation) may limit N accumulation (Hyvärinen and Crittenden 1998).

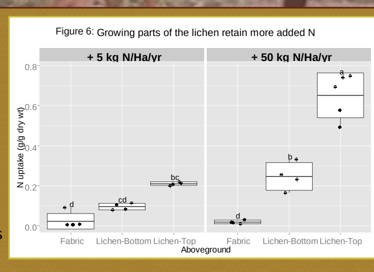


Figure 6: Growing parts of the lichen retain more added N

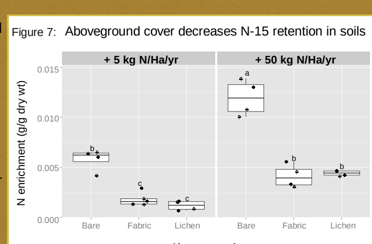


Figure 7: Aboveground cover decreases N-15 retention in soils

Conclusions:

False lichens provide much the same service as live lichens in reducing transmission of airborne ammonium pollution to soils (fig 5, fig 7), suggesting that the physical structure of lichens is more important than the biological activity of lichens in moderating the effects of N-enrichment on Pinelands soils. However lichens are able to protect groundwater (slightly). Under fabrics, compared with lichens, slightly more N is leached to groundwater (fig 3) and less N is stored aboveground (fig 6). My next project will be in an urban context, studying how epiphytic lichen communities change with human population and to what extent urban lichens absorb metal pollution.

ACKOWLEDGEMENTS:

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References

Dighton, J., Tuninga, A. R., Gray, D. M., Huskins, R.E. and Belton, T. 2004. Impacts of atmospheric deposition on New Jersey pine barrens forest soils and communities of ectomycorrhizae. *Forest Ecology and Management* 201(1)131-144.

Dahlman, L., Nasholm, T. and Palmqvist, K.. 2002. Growth, nitrogen uptake, and resource allocation in the two tripartite lichens Nephroma Arcticum and Peltigera Aphthosa during nitrogen stress. *New Phytologist* 153 (2): 307-15.

Hogan, E., P. Crittenden, L. Sheppard, A. Crossley, I. D. Leith, and P. Ancion. 2010. The influence of nitrogen deposition on phosphatase activity in *Cladonia portentosa. New Phytologist*, 186(4): 926-33.

Hyvärinen, M., and P.D. Crittenden. 1998. Relationships between atmospheric nitrogen inputs and the vertical nitrogen and phosphorus concentration gradients in the lichen *Cladonia Portentosa." New Phytologist*, 140(3): 519-30.

Magnani, F., Mencuccini, M., Borghetti, M. Berbigier, P., Berninger, F., Delzon, S. Grelle, A. et al. 2007. The human footprint in the carbon cycle of temperate and boreal forests. *Nature* 447 (7146): 849-51.

Miller, J. E., and D. H. Brown. 1999. Studies of Ammonia Uptake and Loss by Lichens. *The Lichenologist* 31 (01): 85.