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FINAL REPORT

TITLE: Modelling regulation of decomposition and related roo..mycorrhizal processes in arctic tundra soils

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Work was completed in the final year of Phase I of the R4D program that focused on the following activities: 1. Finish acquiring soil and root-mycorrhizal samples from the R_4D Imnaviat Creek watershed site. 2. transfer process sampling protocol to Schimmel and Chapin so that they can utilize similar approaches in their work on nitrogen dynamics in field manipulation studies and there by better integrate existing decomposition data and modelling structure with their data and information on nitrogen dynamics in soils and plant compartments. 3. Finalized data sets on the complete mineralization of cellulose, and cellulose like plant structural material, and cellulose intermediate hydrolysis products into CO2 from soils from water track and non-water track soils and soils from riparian sedge moss meadow vegetation areas. 4. Finish data collection and writing manuscript on the uptake potential of organic phosphorus by *Eriophorum vaginatum* and finalize work on comparative study in a forest soil of similar pH, but which had been limed in an attempt to alter soil pH. 5. Initiate study on looking at epilithic biofilm in boreal streams so that we could have a better understanding of the differences in decomposition processes these systems relative to similar data from various arctic tundra soils. 6. Developed and tested the GAS models on decomposition and plant growth and nutrient acquisition.

Since this was the final year of this project principal activities were directed towards either collecting data needed to complete existing incomplete data sets or writing manuscripts. Data sets on Imnaviat Creek watershed basin are functionally complete and data is finialized on the cellulose mineralization and dust impact on soil organic carbon and phsophorus decomposition. Seven manuscripts were prepared, submitted or accepted during this reporting period. They are briefly outlined below:

1. The absorption of inorganic phosphate from ^{32}P-labeled inositol hexaphosphate by *Eriophorum vaginatum*. 1991. C.J. Kroehler and A.E. Linkins, Oecologia 85, 424-428.

A scarcity of available phosphorus often limits plant growth, and organic forms of phosphorus are not generally thought to be important direct sources of phosphate for plants. A dominant arctic tundra plant, *Eriophorum vaginatum*, is able to hydrolyze and absorb phosphate from a naturally occurring organic phosphorus

compound at concentrations as low as those found in soil solution and at rates comparable to its ability to absorb inorganic phosphate. Calculations show that in tundra soils, where organic phosphorus is typically the predominant form of phosphorus in soil solution, *E. vaginatum's* root surface phosphatases may be capable of providing from organic phosphorus up to 69% of the plant's annual phosphorus demand.

2. Phosphatase activities and phosphorus uptake from inositol phosphate by ectomycorrhizal fungi. 1991. R.K. Antibus, R.L. Sinsabaugh and A.E. Linkins. Can. J. Bot. 70, 794-801.

To better understand the physiological importance of acid phosphatase activity we examined the effects of inorganic and organic phosphorus growth sources on enzyme activity and ^{32}P uptake in several ectomycorrhizal fungi. Mycelium of eight isolates from four basidiomycete species demonstrated optimal p-nitrophenyl phosphatase activity at pH 4.5 or 5.0. Acid phosphatase activities varied between strains of Scleroderma citrinum and between the species examined. Inter specific differences in isozyme patterns of whole cell extracts were apparent in native polyacrylamide gels. The isoelectric points of the predominant phosphatases in whole cell extracts were in the pH 5.0 to 5.5 range. Growth of fungi on inositol hexaphosphate versus inorganic P did not affect the isozyme patterns detected by either electrophoretic method. Growth on inositol hexaphosphate effected surface and soluble activities towards p-nitrophenyl phosphate and inositol phosphate to different degrees in species examined. Phytase activity was sufficient to produce a net release of P in all isolates. Growth on inositol hexaphosphate was associated with increased uptake of ^{32}P from inositol polyphosphate in four of five species examined. Acid phosphatase, measured with p-nitrophenyl phosphate, was positively correlated with ^{32}P uptake. Decreased phytase activities measured for inositol hexaphosphate grown mycelium were associated with increased P influx in such mycelium. Both phosphatase activity and ^{32}P uptake were subject to inorganic P inhibition with ^{32}P uptake demonstrating a greater sensitivity. These results provide further evidence for the role of surface acid phosphatases in organic P utilization by ectomycorrhizal fungi.

3. Effects of liming a red pine forest floor on mycorrhizal numbers and mycorrhizal and soil acid phosphatase activities. 1992. R.K. Antibus and A.E. Linkins, Soil Biol. Biochem. 24, 479-487.

The forest floor of a New England red pine plantation was limed to determine whether this would influence the numbers or types of ectomycorrhizas associated with this host. The potential effect of lime on the mineralization of soil organic phosphorus was examined by determining the surface phosphatase activities of

common ectomycorrhizal types, their reaction to pH and soil phosphatase activities.

Differences in numbers of viable ectomycorrhizas (ECM) between a control and a limed plot were small relative to the high amount of spatial and seasonal variability over 2 field seasons. Numbers of distinct ECM morphotypes were used to calculate diversity indices. Diversity changed seasonally, with two to five common ECM morphotypes encountered at each date. Liming did not appear to affect diversity of ECM morphological types, however, lime did increase the relative frequency of certain ECM morphotypes. The causes for these shifts are not known.

Surface phosphatase activities of ECM morphotypes from both limed and unlimed soil were optimal at pH values of 3.5 and 5.0. Seasonal and liming-related differences were observed for phosphatase activity of individual ECM morphotypes, but these differences were minor compared to differences existing among morphotypes.

Liming reduced soil phosphatase activity assayed at pH 5.0 and 7.0 in the 012 horizon. No differences in activity were apparent in the 02 or A1 horizons, although liming altered the pH of these horizons. The decline in activity paralleled changes in soil water content.

Ectomycorrhizas are a significant component of the forest floor in red pine plantations and produce high levels of surface acid phosphatase activity. Lime-induced shifts in ECM morphotypes have the potential to alter the mineralization or organic P and the P nutrition of the host. The extent to which shifts in ECM associates contribute to the observed decrease in the phosphatase activity of the 012 horizon remains to be determined.

4. An enzymic approach to the analysis of microbial activity during plant litter decomposition. 1991. R.L. Sinsabaugh, R.K. Antibus and A.E. Linkins, Agriculture, Ecosystems and Environment 34: 43-54.

The microbial degradation of plant litter is mediated by extracellular enzymes. Their specificity makes enzyme assays useful for comparing microbial communities, monitoring community succession, evaluating the effects of disturbance or ecosystem variables on microbial processes and for studying microbial processes at the molecular level. Thus far, the application of enzymic techniques to ecological studies of plant litter decomposition has been limited. Applied in combination with general indices of microbial biomass and activity, taxonomic analyses and process rate measurements, enzyme assays offer a mechanistic approach to decomposition studies. This potential is illustrated by discussing the role o cellulase in leaf litter degradation and by proposing a conceptual model of plant litter degradation from an enzymic perspective.

5. Exoenzyme accumulation in epilithic biofilms. 1991. R.L. Sinsabaugh, D. Repert, T. Weiland, S. Golladay and A.E. Linkins. Hydrobiologia 222: 29-37 (1991).

Although exoenzyme accumulation if often proposed as an explanation for the high metabolic activity of biofilms, little is known about the abundance, distribution and turnover rates of exoenzymes within these communities. To assess accumulation, epilithic biofilm samples were collected from a fourth-order boreal river and homogenized. The resulting particles were fractionated by size and each fraction was assayed for nine exoenzyme activities, chlorophyll, and ATP.

In general, carbohydrase activities were not correlated with microbial biomass indicators; the largest pool of activity was in the aqueous phase (<0.2 μm). Phenol oxidase, peroxidase, and phosphatase activities were largely particle-bound and often correlated with microbial biomass distribution. It was concluded that the epilithic biofilm matrix was effective at accumulating carbohydrase activity and that this accumulation may partially account for the metabolic resistance of epilithic biofilms to dissolved organic matter fluctuations.

6. Wood decomposition over a first-order watershed: Mass loss as a function of lignocellulase activity, R.L. Sinsabaugh, R.K. Antibus, A.E. Linkins, C.A. McClaugherty, L. Rayburn, D. Repert and T. Weiland, Soil Biol. Biochem. 24, 743-749 (1992).

Because plant litter decomposition is directly mediated by extracellular enzymes, analyses of the dynamics of their activity may clarify the mechanisms that link decomposition rates to substrate quality and to temperature, moisture and nutrient availability patterns. We investigated this possibility by placing arrays of white birch ice-cream sticks at eight upland, riparian and lotic sites on a forested watershed in northern New York. For 3 yr, samples were analyzed for mass loss, protein, nitrogen and phosphorus accumulation and the activity of 11 classes of extracellular enzymes involved in lignocellulose degradation and nutrient cycling. Despite considerable heterogeneity both within and between sites, decomposition rates were closely related to the activity of lignocellulose-degrading enzymes. A statistical model was developed that accounted for 94% of the variance in mass loss rates as a function of the temporally-integrated activity of these enzymes. Models of this type contribute to our understanding of scale integration and may facilitate the estimation of decomposition rates among landscape units.

7. Extracellular acid phosphatase activities in *Eriophorum vaginatum* tussocks: A modeling synthesis. 1992. D. Moorhead, C. Kroehler, A.E. Linkins and J.F. Reynolds, Accepted for publication: Arctic and Alpine Research

Analyses of *Eriophorum vaginatum* tussocks provided mass and kinetic parameters for a Michaelis-Menten model of phosphatase activities in Alaskan tussock tundra. This model was used to simulate the temporal patterns of phosphatase activities, given a 90-d thawing season and organic phosphorus concentrations of 30 μM in the first and last 10-d intervals; 15 μM at other times. Results indicated that about 28% of the total annual tussock activity (155 mg P released) occurred during the brief period of high substrate availability in autumn; little occurred in spring because most of the tussock was frozen and live root mass was low. Phosphatases associated with living roots of E. vaginatum were responsible for about 4% of the total activity in tussocks (ca. 6 mg P), which is almost twice the annual plant demand (ca. 3.5 mg). These results suggest that (1) *E. vaginatum* may obtain much of its phosphorus requirement from the activities of root surface phosphatases, and (2) the timing of maximum plant phosphorus uptake (late in year) and growth (early in year) are asynchronous, i.e., E. vaginatum integrates nutrient availabilities across years.

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