THE ECOLOGY OF NITROGEN CYCLING

Teri Balser [1/]

In order to truly understand the behavior of nitrogen in the soil, it is important to understand the reasons *why* it cycles; why and how soil microorganisms use nitrogen. For example, unlike plants soil bacteria can use some forms of nitrogen as an energy source rather than simply for biomass production. Their nitrogen needs and ability to compete for it in the soil are unique. In this talk, we will take an alternative view and explore the hows and whys of the nitrogen cycle from the perspective of soil microorganisms. We will see that nitrogen cycling is a consequence of the growth and activity of microorganisms, and that an understanding of how to 'think like a microbe' can help us have a greater understanding of plant-soil nitrogen dynamics.

First, we'll take a look at the N cycle. We've all seen this before, but have we ever really looked at it from the organisms' perspective? We'll examine some of the reasons nitrogen cycles in the soils, and where are the important points of control. Finally, we'll discuss how the ecology of soil organisms might contribute to soil quality, and management issues. Our ability to manage soil and fertilizer inputs for sustainable yield and environmental quality may depend on a greater understanding of soil ecology.

Talk Summary Points

1) We will investigate the *pools* of N in soil, and examine the fluxes between pools.

2) We will focus on a couple of the processes more specifically.

3) Nitrogen fixation is the first process in the N cycle. N must be fixed from N_2 gas to an organic form. This is an incredibly energy intensive process. This is why nitrogen is so often limiting in terrestrial ecosystems.

4) Mineralization is the transformation of N-org to NH_4^+. It is carried out by nearly all organisms in soil (all heterotrophs). It happens whenever N is in excess of carbon needs. If there is too little N to use up the carbon present, then N must be immobilized from the soil surrounding, or else growth stops.

5) Mineralization only happens when microorganisms are forced to give up the nitrogen – usually when they are eaten or killed. Plants may have ways to force microbial N turnover – as can be seen in examples of rhizosphere carbon and nitrogen dynamics.

[1/] Assistant Professor, Department of Soil Science, Univ. of Wisconsin-Madison.

6) The transformation of NH_3 to NO_2^- to NO_3^- is ‘nitrification’. We care about this transformation because NO_3^- is far more readily lost from the system than NH_4^+. Also, some plants prefer NO_3^- as an N source.

7) Nitrification happens in two steps, and is a ‘narrow’ taxonomic process (carried out by a limited number of organisms). Nitroso and Nitro genera are examples of specialized Gm- bacteria that fill an ecological niche – using NH_3 as an energy source, and fixing CO_2. Oxygen is the terminal electron acceptor, thus oxygen is required.

8) The form of the ion is important: NH_3 is volatile, and is the only form that can be nitrified. The enzyme responsible is AMO, or ammonium monooxygenase. Thus nitrification is pH dependent (lower pHs favor NH_4^+ over NH_3).

9) NO_2^- (nitrite) is extremely reactive, and is thus rarely found in solution. Nitrification depends on the availability of substrate – ammonium oxidizers must be found in close proximity to nitrite oxidizers (e.g., a mini-consortium).

10) Generating energy using NH_3 as an electron donor is a very inefficient way of making a living – for every one mole of N fixed as biomass, nitrification requires approximately 16 times the NH_3 to generate energy. Thus ammonia oxidizers (and nitrite oxidizers) grow very slowly in soil, and have been thought to be poor competitors for nitrogen.

11) Addition of ammonia-based fertilizer tends to favor nitrifying activity by alleviating some of the competition for nitrogen among heterotrophic microorganisms, plants and nitrifiers.

12) Denitrification closes the cycle – NO_3^- gets transformed back to N_2 gas. It happens in several steps. It is carried out by facultative anaerobes, using NO_3^- etc. as alternative electron acceptors. Under ideal conditions, NO_3^- goes straight to N_2. When conditions aren’t ideal, then trace gases get released at points along the way.

13) Soil quality might be a function of the microbial community present as much as it is other factors. Our ability to manage soil and fertilizer inputs for sustainable yield and environmental quality may depend on a greater understanding of soil ecology.