Soils are Alive Newsletter

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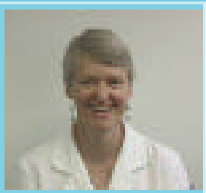
Centre for Land Rehabilitation — The University of Western Australia



Lyn Abbott

Welcome...
This is the first issue of the *Soils are Alive* Newsletter for 2001.

Soil Biological Fertility

The home of soil organisms is affected by every type of land management. No matter how soil is disturbed, it will affect organisms in different ways. It could suit some organisms but not others. For any disturbance, such as addition of chemicals, physical disturbance (such as cultivation) and addition of organic matter such as compost, the numbers of some bacteria, fungi and soil animals will increase but others will decrease.

The major processes that are carried out by soil organisms are :-

- **associated with organic matter decomposition (eg mineralisation)**
- **associated in symbioses with living roots (eg arbuscular mycorrhizas and nitrogen fixation by legumes)**
- **indirectly associated with decompositionof organic matter (eg nitrification)** ***The release of ammonium during mineralisation provides a substance for nitrifying bacteria to use as an energy source***
- **associated with plant disease or biological control of plant disease**
- **associated with degradation of chemicals applied to soil (eg pesticide degradation)**
- **associated with any living organism, irrespective of the process (eg immobilisation - nutrients in organisms become unavailable to plants temporarily)**

A biologically fertile soil has all major biological processes functioning in harmony.

If you have any soil biology questions, please forward them to us by email and we will endeavour to address your question on our website.

ACKNOWLEDGEMENT: The *Soils are Alive* Newsletter and website *www.soilhealth.com* were established in 2000 with support of the Ian Potter Foundation

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Bacteria transform ammonium to nitrate in soil

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Nitrate occurs commonly in soil. Only a few specific groups of microorganisms are capable of transforming ammonium ions to nitrate. The most studied of all soil nitrate makers are the nitrifying bacteria.

In the soil nitrate making process, nitrifying bacteria work as a team. Some nitrifying bacteria oxidise ammonium to nitrite and are called ammonium oxidisers. Nitrite is then converted to nitrate by another group of nitrifying bacteria known as nitrite oxidisers. The most commonly known genus of ammonium oxidizing bacteria is *Nitrosomonas* and *Nitrobacter* is a common genus of nitrite oxidising bacteria (Figure 1).

Ammonium → Nitrite → Nitrate

Ammonium oxidizers *eg.Nitrosomonas* — Nitrite oxidizers *eg Nitrobacter*

Figure 1. The pathway for production of nitrate by nitrifying bacteria

Like most bacteria, nitrifying bacteria are invisible in the soil, except with the aid of a powerful microscope and special stains. They occur mostly in the top 10 cm of the soil profile. They represent only about 1 to 3% of the total number of bacteria in soil. This means there are about 100,000 nitrifying bacteria per teaspoon of soil.

Prediction of soil nitrate production

Generally a greater number of ammonium oxidising bacteria than nitrite oxidising bacteria is required for conversion of ammonium to nitrate.

The actual proportion of the numbers of these two groups of bacteria depends on the soil type (Figure 2).

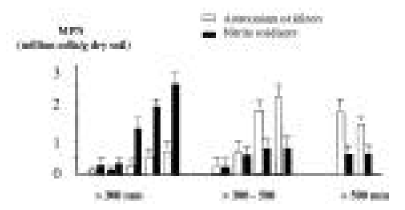

Figure 2 Number of nitrifying bacteria in soil from different rainfall regions detected using the most probable number (MPN) method

It is important to note that the number of nitrifying bacteria present in a soil is not always related to the nitrate producing activity of the soil. However, the ratio of ammonium to nitrite oxidising bacteria is related to the nitrate producing activity of the soil. A ratio of 1:3 appears to result in maximum activity of nitrate production in the soil from the wheatbelt in south-western Australia (Figure 3). This means that there needs to be three times as many nitrite oxidising bacteria than ammonium oxidising bacteria for maximum nitrifying activity.

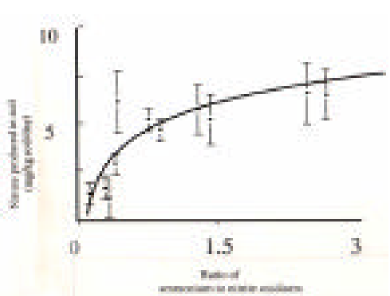

Figure 3. Soil has maximum production of nitrate when there is a 1:3 ratio of ammonium oxidizing bacteria to nitrate oxidising bacteria.

Is production of nitrate significant?

Nitrate production in soil is a significant part of the nitrogen cycle in all environments and the process is called ***nitrification*** (Figure 4).

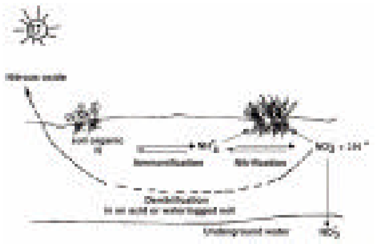

Figure 4 This is a summary of how nitrification fits with other processes in the nitrogen cycle.

Nitrification is a process that links the two forms of nitrogen (ammonium and nitrate). These forms of nitrogen are both used by microbes and microfauna in soil as well as by plants. As a consequence, the nitrification processes are of fundamental importance in determining the form of soil nitrogen.

In agricultural soil, the contribution of nitrification to the state of soil N is less than in natural ecosystems. Most nitrogen in agricultural soil is supplied by chemical fertilisers and the role of nitrification has become an important factor in identifying a required level of application of nitrogen fertilisation.

How much is nitrate being produced in the soil?

The amount of nitrate produced in soil is highly variable. It depends on the availability of nitrogen and on environmental conditions being suitable for the nitrifying organisms.

For example, when soil is moist and warm in spring, a 100% conversion of urea to nitrate is completed in a few days. The microbial enzyme urease transforms urea into ammonium. Urease is produced by many bacteria in soil. Then the nitrifying bacteria convert ammonium to nitrite and nitrate.

The nitrification process may take a few weeks before it commences in soil after it is amended with crop residue. This is because some of the nitrogen in plant residues can take about this long to be released through the process of mineralisation (see *Soils are Alive* Newsletter 1(4)). Soil characteristics such as pH and bulk density can influence the rate of soil nitrate production.

Does an increase in soil organic matter increase nitrate production?

An increase in soil organic matter does not necessarily lead to an increase in nitrate production in soil. When organic matter is mineralised, ammonium may be released into soil. This only occurs if there is excess nitrogen to meet the requirements of the soil organisms in the organic matter. This is usually the case for oganic matter from legumes. Nitrogen is released into soil may be taken up by roots or soil microorganisms. If this does not occur immediately, there is a chance that it will be transformed to nitrate.

Unlike many other soil microrganisms, nitrifying bacteria are not dependent on organic matter to meet their need for carbon. They obtain their carbon from carbon dioxide, as plants do.

Increasing organic matter in soil is a key factor in sustaining the quality of farmland (see *Soils are Alive* Newsletter 1(4)). Changes in levels of soil organic matter alter the environment of soil which is the home of a great diversity of microbial communities. Communities of nitrifying bacteria are very sensitive to changes in the soil environment, especially if the pH of the soil drops to to more acidic levels (eg below pH 4.5)

Can farmers save money on nitrogen fertilizer?

Nitrogen fertiliser acts as like a fast-food in soil, particularly for nitrifying bacteria in spring. Excess ammonium in soil can be quickly converted to nitrate unless it is taken up by microorganisms or plants first. Nitrate is very mobile in soil and can easily move away from the root zone and find its way into ground water and rivers. Nitrate leaching has been estimated to cost the Australian wheat industry millions of dollars annually in lost production.

Factors that affect nitrate leaching

The ability of soil to hold onto nitrate depends on its texture. Generally this is determined by the content of non-living materials that include sand, silt, clay and organic matter. An example of such a soil is one that contains sand, silt and clay in equal proportion and is called a loam.

Clay has a major effect on the leaching of nitrate. Clay particles are very small and have negatively charged surfaces. They attract positive ions such as potassium and ammonium. Nitrate has a negative charge and it is not attracted to clay so it stays in the water between the soil particles (this water is called the soil solution).

Organic matter can reduce soil nitrate leaching. The degraded residues of plants and animals contain positively charged ions (humic compounds). Many tropical soils contain high levels of organic matter compared to temperate soils. The higher organic matter level gives the soil an overall positive charge that can bind nitrate and prevent it from leaching.

CROPPING TIME
Plants are key to the uptake of nitrogen in soil and prevention of build up of nitrate. For example, a summer crop can be used in a mediterranean environment (providing there is sufficient moisture) to use the nitrogen released by mineralisation of organic matter. If there is no summer crop, the nitrogen is likely to be lost due to nitrate leaching.

CHEMICAL APPPLICATION
Some commercial pesticides can inhibit soil nitrate production. They do this mainly by either stopping or slowing down the activity of ammonium oxidising bacteria.

GRDC
Grains Research & Development Corporation

Nui Milton, is a Research Scientist funded by GRDC. She is investigating soil measurements as indicators of soil biological fertility.

See website **soilhealth.com** *for colour version of all newsletters*