SOIL BIOLOGICAL FERTILITY

Key points
- Soil fertility depends on three major interacting components: biological, chemical and physical fertility.
- Soil organisms improve soil fertility by performing a number of functions that are beneficial for plants. This article examines six of these functions.
- Some management practices may help improve and maintain the biological fertility of soil.

Releasing nutrients from organic matter
Soil microorganisms (figure 1) are responsible for most of the nutrient release from organic matter. When microorganisms decompose organic matter, they use the carbon and nutrients in the organic matter for their own growth. They release excess nutrients into the soil where they can be taken up by plants. If the organic matter has a low nutrient content, micro-organisms will take nutrients from the soil to meet their requirements.

For example, applying organic matter with carbon to nitrogen ratios lower than 22:1 to soil generally increases mineral nitrogen in soil. In contrast, applying organic matter with carbon to nitrogen ratios higher than 22:1, generally results in microorganisms taking up mineral nitrogen from soil (Hoyle et al. 2011).

Fixing atmospheric nitrogen
Symbiotic nitrogen fixation is a significant source of nitrogen for Australian agriculture and may account for up to 80% of total nitrogen inputs (Unkovich 2003). In the symbiosis, rhizobia or bradyrhizobia fix nitrogen gas from the atmosphere and make it available to the legume. In exchange, they receive carbon from the legume. The symbiosis is highly specific and particular species of rhizobia and bradyrhizobia are required for each legume. For more information see fact sheet “Legumes and Nitrogen Fixation”.

Increasing phosphorus availability
Most agricultural plants (except lupins and canola) form a symbiosis with arbuscular mycorrhizal (AM) fungi (figure 2) that can increase phosphorus uptake by the plant. The hyphal strands of AM fungi extend from plant roots into soil and have access to phosphorus that plant roots cannot reach. The AM fungi can provide phosphorus to plants and in return they receive the carbon they need to grow.

Importantly, this symbiosis is only beneficial for plants when available phosphorus in soil is insufficient for the plant’s requirements. Increasing phosphorus availability may be especially beneficial on phosphorus fixing soils in Australia, which are widespread and can store 100 kilograms of phosphorus per hectare (Cornish 2009).

Degrading pesticides
The degradation of agricultural pesticides in soil is primarily performed by microorganisms. Some microorganisms in soil produce enzymes that can break down agricultural pesticides or other toxic substances added to soil. The length of time these substances remain in soil is related to how easily they are degraded by microbial enzymes.

Controlling pathogens
Some microorganisms and soil animals infect plants and decrease plant yield. However many organisms in the soil control the spread of pathogens. For example, the occurrence of some pathogenic fungi in soil is decreased by certain protozoa that consume the pathogenic fungi. The soil food web contains many relationships like this that decrease the abundance of plant pathogens.
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Improving soil structure

Biological processes in soil can improve soil structure. Some bacteria and fungi produce substances during organic matter decomposition that chemically and physically bind soil particles into micro-aggregates. The hyphal strands of fungi can cross-link soil particles helping to form and maintain aggregates (figure 3). A single gram of soil can contain several kilometres of fungal hyphae (Young and Crawford 2007). In addition, soil animals increase pores by tunnelling through soil and increase aggregation by ingesting soil.

Figure 3: Fungal hyphae (shown in blue) extending through soil (image Karl Ritz).

Managing soil biological fertility

We currently understand less about how management practices affect soil biological fertility than how they affect soil chemical and physical fertility. However, the management practices described below may help improve and maintain the biological fertility of soil.

1. Minimise erosion as soil organisms are predominantly located in the surface layers, which are most easily eroded.
2. Maintain or increase the organic matter content of soil as organic matter is an important source of carbon, energy and nutrients for soil organisms.
3. Use diverse rotations as they result in diverse inputs of organic matter and a diverse population of soil organisms.
4. Select nitrogen fixing bacteria that match the host plant and can tolerate your soil characteristics (e.g. pH) as nitrogen fixing bacteria form specific associations with legumes.
5. Consider the release of nutrients from organic matter when determining fertiliser applications.
6. Use fertiliser inputs that complement the activities of arbuscular mycorrhizal fungi as they only increase plant uptake of phosphorus in phosphorus-deficient soils.
7. Choose crop rotations and management practices that decrease the suitability of soil for plant pathogens.
8. Be patient as soil biological processes take time to develop.

Did you know?

- There are more organisms in a handful of soil than there are people on Earth, but most of them can only be seen under a microscope.
- The weight of organisms in the surface 10 cm of a cropping soil in southern Australia can be as much as 2 t/ha.
- About a quarter of all the organisms in an agricultural soil are located in the surface 2 cm of soil.
- At any one time, most soil organisms (>70%) are inactive as soil conditions are not usually optimal.
- Although there are a few pest nematodes species, there are over 95 non-pest species (figure 4).

Figure 4: A non-pest soil nematode (image Karl Ritz).

Further reading and references