# Soil Biology

FACT SHEET 7

**The soil is a living, breathing ecosystem where a vast diversity of organisms make up the soil food web. The soil is home to the greatest biodiversity on the planet, a teaspoon (1 gram) of healthy soil may contain more than a billion individual organisms. Diverse populations of living organisms are vital for effective nutrient cycling within the soil.**

## The role of soil organisms

Soil organisms range in size from microscopic single celled bacteria, to fungi, algae, protozoa, to larger and more complex nematodes and arthropods and then to the more visible organisms such as earthworms, dung beetles, insects spiders and small vertebrates. All have specialised roles within the soil and all rely on plants as their primary source of energy.

This community of soil organisms is often referred to as the soil food web. Most obtain their energy and carbon by consuming plant material or plant compounds and other organisms. In doing so nutrients are cycled through the soil and made available for uptake by plants and other soil organisms. In the natural environment all plants depend on the soil food web for their nutrients.

Other roles of soil biology include enhancing soil structure and aggregate stability. Fungi and the exudates of bacteria provide the 'glue' that bind soil particles. As the only organisms capable of degrading carbon they are the first involved in the decomposition of organic matter. They also provide a food source for higher organisms as they are predated.

Through their movement through the soil larger organisms create passages in the soil profile enhancing the infiltration of rainfall. Combined with improving soil structure these attributes serve to increase the water holding capacity of soil and plant available water.

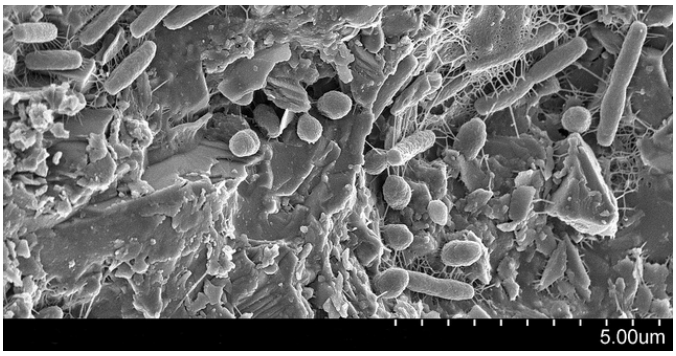


Figure 1: Bacteria and fungal colonies on the surface of a grain of sand.

## The structure of the soil food web

The structure and potential size of the soil food web in any environment will be influenced by a range of soil factors including soil type (particularly the percentage clay content), porosity and vegetation. Management also plays a significant role in effecting soil conditions to enhance biology activity and population structure.

Table 1: Typical numbers of different organisms in a healthy agricultural soil.

| Organism | Typical numbers |
|---|---|
| Bacteria | 100 million - 1 billion/gram |
| Fungi | Several metres/gram |
| Protozoa | Several thousand flagellates & amoebae and >100 ciliates/gram |
| Nematodes | 10-20 bacterial feeders/gram |
| Arthropods | Up to 900/$m^2$ |
| Earthworms | 50 or more/$m^2$ |

**More information on the effects of management is provided in Factsheet 8 of this series**

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## Types of soil organisms

**Bacteria** – in terms of numbers bacteria dominate the soil biota. Bacteria are concentrated in the rhizosphere, the narrow zone immediately adjacent to plant roots. These single celled organisms are the primary decomposers and consume simple sugars, root exudates and fresh plant litter.

**Fungi** – usually dominate the soil biota biomass. Growing as long threads known as hyphae, fungi are microscopic cells which are capable of penetrating between soil particles. Saprophytic fungi are important decomposers and have a key role in breaking down more resistant carbon compounds such as hemicellulose and lignin. The hyphae also bind soil particles improving aggregate stability.

Cellulolytic microbes, specialised bacteria and fungi, are the only organisms with the capacity to break bonds within chains of carbon compounds (cellulose) into simple molecules such as glucose. In this form these molecules can then be utilised by a vast range of microbes and other organisms. These organisms also retain nutrients in their body mass and are predated by larger organisms in the food web, contributing to nutrient cycling. They also produce substances that bind soil particles into aggregates improving soil structure.

**Mycorrhizal fungi** are a special group which have a symbiotic association with plants. With the exception of the brassicas, most trees and agricultural plants benefit from this association. Mycorrhiza penetrate the cells of plant roots and the hyphae may extend for many metres through the soil. The plant benefits from the mycorrhiza providing greater access to soil water and nutrients, particularly phosphorus. In return the plant provides the mycorrhiza with a source of nutrient.

Mycorrhiza have been known for many years but new discoveries around their importance for increasing soil carbon and roles of the hyphal network are relatively new. The hyphae may form a plant internet where plants communicate via hyphal networks activating defences against pests or pathogens.

Glomalin, a type of mycorrhizal fungi, was found to account for 27% of soil carbon and is a major component of soil organic matter. Another study showed the resilience of glomalin in that it may persist in soil from between 7 and 42 years depending on conditions.

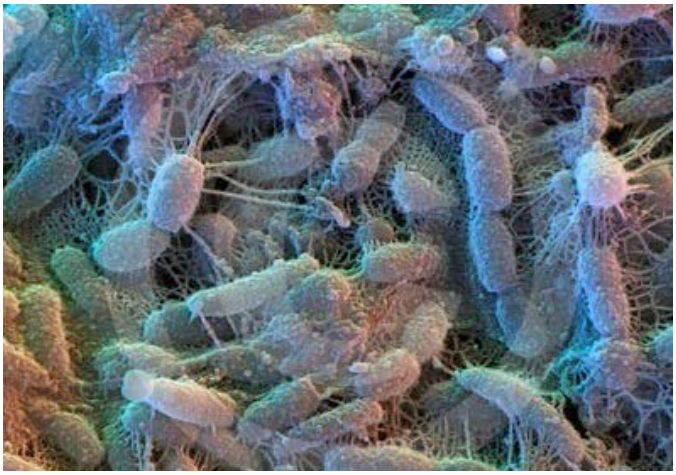

Figure 2: A vast diversity of soil bacteria and fungi exist.

**A teaspoon of healthy soil may consist of up to a billion individual organisms**

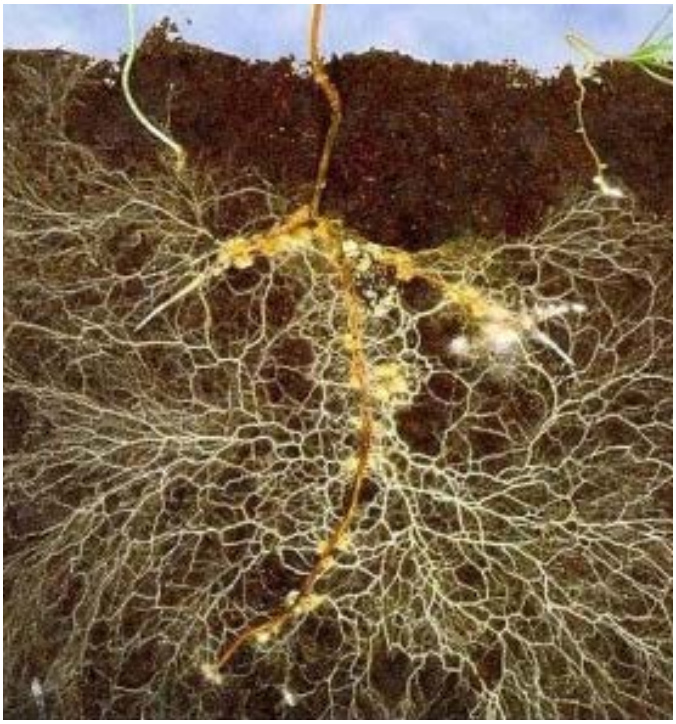

Figure 3: Mycorrhizal fungi produce a network of mycellial hyphae greatly enhancing a plants capacity to access nutrients, particularly phosphorus and soil moisture.

**As well as contributing to plant nutrition, glomalin and other mycorrhizal fungi are significant contributors to soil carbon**

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**Protozoa** are also single celled organisms but many times larger than bacteria which are their main food source. Protozoa can consume up to 10,000 bacteria per day. They have a lower concentration of nitrogen in their bodies than the bacteria they consume and the excess nitrogen is released as NH4+ usually near the plant root. By grazing on bacteria they stimulate bacterial population growth and nutrient cycling.

There are three main groups, ciliates, amoebae and flagellates of which ciliates are the largest. Protozoa also reside in soil pores and move through soil water and water films associated with soil particles. By stimulating bacterial growth they accelerate decomposition rates of soil organic matter.

**Nematodes** are microscopic non segmented worms. They are classed as either bacterial feeders, fungal feeders or predatory nematodes. The predatory nematodes consume protozoa and other nematodes or may be omnivores which consume a variety of organisms. Most nematodes perform beneficial roles in the soil but more is known about the disease causing nematodes and root feeding plant parasites.

A huge diversity of nematodes exist and have a range of functions in the soil food web. As well as nutrient cycling, population control and disease suppression nematodes also assist in the distribution of microbes, bacteria and fungi, throughout the soil either by transporting them on their body surface or in their digestive tract.

**Earthworms** are the most obvious and perhaps the best known members of the soil food web. They are primary decomposers of dead and decaying organic matter. Earthworms obtain most of their nutrition from the bacteria and fungi that grow and feed on the surface of the organic matter.

In moving through the soil, earthworms can create channels which enhance soil structure and water infiltration rate. These channels may persist for long periods enhancing soil porosity and drainage. They also create opportunity for increased plant root growth deeper into the soil.

The faeces, or castings of earthworms, contain more microorganisms than the organic matter that they consume. They mix soil and their castings effectively aggregate soil particles increasing soil water holding capacity. They fragment and inoculate organic matter increasing nutrient cycling and plant available soil nutrients.

Figure 4: The most dominant type of protozoa are the ciliates, The hair like cilia around their body enable movement through films of water on soil particles.

**A single protozoa can consume up to 10,000 bacteria each day**

## Nutrient cycling

The predation of soil organisms contributes to nutrient cycling within the soil system. As soil organisms consume other smaller organisms the nutrients in the body mass of organisms are cycled. For example bacteria may have a C:N ratio of 5:1 and protozoa have a lower concentration of nitrogen, a C:N ratio of 20:1. The excess nitrogen is usually released as $NH^{4+}$, a plant available form of N, usually near the plant root. Table 1 shows the average C:N ratios of different types of organisms.

Figure 5: The familiar sight of a soft slimy earthworm working through soil particles.

Table 1:
Approximate carbon:nitrogen ratios of the biomass of different organisms.

| Organism | C:N Ratio |
|---|---|
| Bacteria | 3-10:1 |
| Fungi | 10:1 |
| Protozoa | 10-30:1 |
| Green plant leaves | 30:1 |
| Nematodes | 100:1 |
| Dried plant leaves | 150-200:1 |

Arthropods can range in size from microscopic to several cm in length. Organisms within this group include ants, insects, springtails, collembola, beetles, dung beetles, spiders, mites, centipedes and millipedes. There name is derived from their jointed (arthros) legs (podos).

Most arthropods live on or near the soil surface to 10cm depth. Depending on their function are referred to as;

**shredders** e.g. millepedes, termites, other mites, roaches

**predators** e.g. centipedes, spiders, beetles, ants

**herbivores** e.g. mole crickets and cicadas or

**fungal feeders** e.g. cicadas, mole crickets

Figure 6.
A vast diversity of soil arthropods exist with a range of functions in the soil.

Arthropods stimulate biological activity as they graze on bacteria and fungi, mix microbes with their food, shred organic matter allowing microbial access to a greater surface area, mineralise nutrients and excrete nutrients in plant available form.

Like earthworms as they move and burrow through the soil they create channels and shape habitat, enhancing porosity, water infiltration and aggregate stability.

## The soil food web

The potential size and diversity of the soil food web in any environment depends foremost on the biomass of plants grown and roots present. The greater the foundation more organisms at every level may be supported. The basic needs for beneficial soil organisms to grow and thrive are;

1. a food source in the form of organic matter primarily derived from plants or other soil organisms
2. well aerated soil, since most beneficial organisms are aerobic and
3. soil moisture. Soil moisture is a primary factor influencing soil biological activity. Soils with greater water holding capacity will have higher biological activity.

**This is the seventh of a series of 12 Factsheets which cover a range of topics regarding soil health and effective function of soil processes.**

## More Information

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