Soils are Alive Newsletter

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School of Earth and Geographical Sciences — The University of Western Australia

Welcome...

This newsletter considers the issue of microbial numbers in soil and the effects of different management practices on the microbial biomass.

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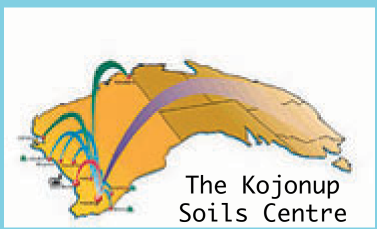
The Kojonup Soils Centre NEWS



The Kojonup Soils Centre has been established to promote knowledge of soil to the farming community and others interested in this important natural resource.

Acknowledgements

This Newsletter was established with support from the Ian Potter Foundation which is also supporting the development of a website on soil health that will be available soon.

The Land Management Society (LMS) initiated the *Know Your Soil Biology:Soils are Alive* workshops that we present throughout Western Australia.

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The fungal-bacterial ratio: Tipping the balance for soil health

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Microbial life in the soil is dominated by fungi and bacteria. Often fungi and bacteria are associated with crop health problems. Most species, however, are a necessary part of the ecosystem and contribute in many different ways to the availability of plant nutrients and plant health.

SOIL ORGANIC MATTER TURNOVER

Soil organic matter increases plant nutrient availability, water-holding capacity and improves soil structure. Management of soil organic matter is therefore a crucial part of agriculture. Its increase and maintenance is a goal in most farming systems. However, this is often not easy to achieve because turnover processes in the soil are not completely understood.

An important living part of the soil organic matter is the microbial biomass, which is an indicator of short-term changes in the soil fertility. The microbial biomass is mainly composed of fungi and bacteria, and at any one time consists of active and inactive parts.

The fungi and bacteria are responsible for the decomposition of plant residues and the release (mobilisation) of plant nutrients in a process called mineralisation. They also immobilise nutrients by accumulating them within the microbial biomass itself and in microbial metabolites. After death of the microbes, plants and other microorganisms use these metabolites and the nutrients released as a food source. However, these mobilisation and immobilisation processes can, at certain times, also lead to excess and deficit of plant nutrients in the soil.

THE ROLE OF FUNGI AND BACTERIA IN THE SOIL

Even though a high proportion of fungi and bacteria are decomposers in the soil, they degrade plant residues differently and have different roles in the recycling of nutrients. This is partly due to their different choice of habitats within the soil and the different types of organic matter they consume.

Fungi are generally much more efficient at assimilating and storing nutrients than bacteria. One reason for this higher carbon (C) storage by fungi lies in the chemical composition of their cell walls. They are composed of polymers of chitin and melanin, making them very resistant to degradation. Bacterial membranes, in comparison, are phospholipids, which are energy-rich. They degrade easily and quickly and function as a food source for a wide range of microorganisms.

The different proportions of C and nitrogen (N) (i.e. different C:N ratios) of bacteria and fungi might also play a role in the mineralisation and immobilisation processes of nutrients in the soil. Due to their structure, fungi need a greater amount of carbon to grow and reproduce and will therefore 'collect' the required amount of carbon available for this from the soil organic matter. Bacteria, however, have a higher nitrogen requirement and therefore a lower C:N ratio and take more nitrogen from the soil for their own requirements.

LAND USE INFLUENCES FUNGAL-TO-BACTERIAL RATIOS

In general, the greater the fertility of a landscape, the greater the soil microbial biomass. The fungal population will increase at a greater rate than that of bacteria, leading to a higher fungal-to-bacterial ratio.

Fungi dominate most of the arable agricultural soils in the temperate climate. Fungal-to-bacterial ratios range from approximately 1.0 to 2.3 but much higher ratios and soils dominated by bacteria are also well documented. Grassland soils are also often dominated by fungi.

Fungi and bacteria differ in their responses to changes in agricultural management practices. Fungi are usually more sensitive to these changes. The fungal-to-bacterial ratio is therefore a good indicator of environmental changes in the soil. When plant residues are applied as mulch, for example, fungi prosper because their hyphae are able to grow into the litter layer. Tilling, however, destroys large amounts of the fungal hyphae. Incorporation of plant residues into the soil also favours the bacterial population because the contact surface between the substrate and bacteria is increased. This response further depends on the soil type.

Nevertheless, the dominance of either fungi or bacteria also depends on the quality of the plant residue. Substrate structure, C:N ratio and cellulose content are important characteristics of its quality. Fungi are the predominant cellulose decomposers, even though one group of bacteria, the Actinomyces also contribute significantly to its decomposition. Cellulose has a high carbon content and a corresponding high C:N ratio, making it the ideal food source for fungi. Bacteria, which have a smaller C:N ratio than fungi, need food rich in nitrogen (e.g. green manure, legume residues). A fertiliser rich in nitrogen therefore favours the bacterial community in a soil whereas a substrate with a relatively wide C:N ratio enables growth of the fungal population.

Fig 1: Hyphae of arbuscular mycorrhizal fungi binding soil particles

The activity of the soil microorganisms also shows strong seasonal variation. Activity increases markedly with increasing temperature and soil moisture. Usually fungi depend on a sufficient amount of water in the soil and are expected to be less active under dry conditions. In many cases a low pH is associated with fungal dominance whereas a high pH might be related to bacterial dominance.

MEASUREMENT OF FUNGAL-TO-BACTERIAL RATIOS

Different methods exist to assess the fungal contribution to the soil microbial community, some of which have been used for over 30 years. Usually the total microbial biomass is estimated by measuring a particular cell constituent or by direct measurement. The active fungal and bacterial population is evaluated either by direct counting or indirectly, via their contribution to soil respiration. New technologies to assess the fungal:bacterial ratio of soils are being developed currently.

Soil microbial populations are measured by relating the biovolume of microscopic counts, extracting group specofoc biological compounds and measuring their concentrations, physiological activities such as catabolig potential (i.e. functional grouping) and substrate induced respiration (SIR). SIR simultaneously measures the activity of the fungi, bacteria and the entire microbial population active at a given time. This technique does not run the risk of adding up inactive or dead microbial components thereby overestimating populations. - a major weakness of the biovolume and extraction methods. However, there are problems with the SIR method that are still under investigation.

The SIR method uses fungicides and bactericides to kill fungi and bacteria, respectively. The fungal and bacterial C contents are separately calculated by tallying the CO2 production of the biocide-treated trials after a period of incubation, with that of an untreated control. The degree of inhibition and the inhibitor additivity ratio (IAR) are calculated by incorporating a fungicide-bactericide treatment into the incubation experiments. These 2 parameters are used to determine the accuracy of the final results. The untreated controls replace the need to measure the basal respiration of soils separately, thus serving as a tool to quantify soil microbial C.

QUESTIONS

1. Is there any advantage to increasing or decreasing the fungal-bacterial ratio?
2. Do you ultimately want it to remain stable?
3. Is having fungi better than bacteria for instance, or do they play separate, equally important roles?

SUMMARY

Soil organic matter content can be maintained or increased by changing tillage practices and by regularly adding organic matter. Mulching, for example, rather than incorporating plant residues into the soil favours the fungal population and increases the soils' ability to hold carbon, therefore creating a more persistent microbial food source and nutrient pool.

Soil organic matter management is very important in creating a sustainable, profitable, system, especially when combined with effective weed and pest control measures.

Progress is being made towards understanding the methodology for assessing fungal-bacterial ratios but some caution in interpreting these data is still required.