JANUARY 2021

SoilWealth NURTURING CROPS

Integrated Crop Protection PROTECTING CROPS

FACT SHEET: SOIL MICROBIOLOGY

A guide for practitioners

BROAD GROUPS OF SOIL MICROBES

Fungi

Moulds: Moulds feed on decomposing plant matter. They require moist, warm conditions to function and reproduce.

Moulds, like all fungi, produce hyphae, or filaments that make up the mycelium of a fungus. Through the mycelium, a fungus absorbs water and nutrients.

Moulds are important for the breakdown of organic matter. They also help to bind soil particles together and can reduce soil borne disease pressure.

Mycorrhizae: They play important roles in plant nutrition, soil biology and soil chemistry. Mycorrhizal fungi form a mutual beneficial (symbiotic) association between a fungus and a plant root. They live partly in the soil and partly in the roots. The major function of mycorrhizae is to exchange nutrients between the surrounding soil (rhizosphere) and their host plant. This occurs via fungal hyphae growing into the soil and increasing the root surface area. Mycorrhizae also protect the plant's roots from pathogens.

Yeasts: While yeasts play an integral role in soil microbial ecology, they are not considered a major soil function group. There still is relatively little known about the importance, function and ecological relationships of yeasts in soil.

Pseudomonas

Important in nutrient cycling and phosphorus availability. They have also been linked to pathogen control and are known to establish an environment suitable for fungi.

Bacteria

Nitrogen-fixing bacteria: These bacteria increase as soil nitrogen decreases.

Aerobic bacteria: These bacteria require both oxygen and water to function. They recycle nutrients and help suppress plant disease.

Anaerobic bacteria: Can perform their role without oxygen being present. Some soil nutrients are only cycled by anaerobic bacteria, however the ratio of anaerobic to aerobic bacteria is important. There should be at least 3:1 but preferably 10:1 aerobic to anaerobic.

Actinomycetes: These specialised bacteria play a role in many functions including the breakdown and cycling of complex compounds such as cellulose. They can also improve soil structure and help compete against pathogens.

SOIL HEALTH DEPENDS ON SOIL MICROBIOLOGY

Soil microbes improve:

- √ Organic matter decomposition
- √ Nutrient cycling
- √ Nutrient availability
- √ Soil air space
- √ Soil water holding capacity
- √ Soil structure and stability.

Hort Innovation ahr applied horticultural research RMCG

This project has been funded by Hort Innovation using the vegetable, fresh potato and potato processing research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

EXPECTED LEVELS

Total levels

Although the recommendation for the level would be as high as possible, a high value does not always indicate good soil conditions. It is the microbial composition in the soil that determines soil and crop health.

Aerobic bacteria levels

Again, it is not the greatest value that is necessarily the best, but the ratio of bacteria to fungi that is important. For pastures for instance, a high proportion of bacteria with a ratio of 0.75:1 fungi to bacteria has been considered ideal (based on colony-forming units or CFUs). In molecular tests (such as PLFA analysis), it's more likely to be 2.3-3.5 (or higher) in pasture.

Newer research has shown that healthy pasture environments are able to support high populations of fungi and bacteria, because of the greater rates of organic matter produced, compared to cropped land in comparable soil and climatic conditions. The high proportion of cellulose, hemicellulose and lignin in pasture residues provides abundant food for fungi (and actinomycetes), which is why their biomass is often several times higher than that of bacteria in well managed pastures.

High bacteria levels can lead to grass weed establishment in crops and poor crop growth for vine and tree crops. High bacteria levels can indicate the land has just come out of pasture, has poor soil structure or low water holding capacity. It can also indicate high use of fungicides and other synthetic inputs.

Low bacteria levels may lead to problems with woody weeds and poor establishment of pasture. They can indicate that the ground has just come out of tree crops or "bush" or has high soil acidity.

Total fungi levels

As with bacteria, it is the fungal to bacteria ratio for the crop grown that is important. Higher proportions of fungi are required for vine and tree crops, with lower proportions for vegetables. A low fungi to bacteria ratio is beneficial for pasture.

High levels of fungi compared to bacteria will encourage woody weeds in pasture and poor pasture establishment. Low levels of fungi restrict sufficient nutrient uptake in vines and trees and poor root establishment.

Actinomycetes levels

The higher the value of these in the soil the better, due to the fact that these bacteria play an important role in the breakdown of complex organic compounds and make nutrients available to plants.

Anaerobic bacteria levels

The ratio of anaerobic to aerobic bacteria is of interest. Less than a third of bacteria levels should be anaerobic and preferably less than 1 in 10. High levels of anaerobic bacteria indicate anaerobic conditions, which can occur with water-logging, compaction, poor soil structure and sustained periods of drought in the soil.

High levels of anaerobic bacteria have been seen when high levels of poorly made "biological" products or effluent have been used.

Azotobacter levels

Azotobacter are nitrogen-fixing bacteria and have a negative correlation with the level of nitrogen in the soil. The higher the level of azotobacter, the less soil nitrogen is available. Therefore there are no desired levels for azotobacter; instead they should be used as an indicator of nitrogen levels in the soil and the ability to cycle nitrogen.

This project has been funded by Hort Innovation using the vegetable, fresh potato and potato processing research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

NUMBERS AND RATIOS

Viable count

A high total microbial count and low viable count indicate the soil environment is right for the growth of the microbe species present (low number of workers working very hard). The viable count could be increased by adding more of the same types of microbes (hard), or by increasing the food source i.e. organic matter (easy), or by introducing new microbe species to the environment (complicated – may die).

A low total microbial count and high viable count works the opposite way indicating the soil environment is not conducive to microbial growth (high number of workers taking too many breaks). Some poorly made composts are a good illustration of this, where they have high viable levels indicating there are good levels of viable microbes, but have a low total count because they are poorly aerated and restrict the growth of those microbes.

This situation would also show up in higher anaerobic counts. Adjusting the physical environment would help increase the total microbial count.

At high total viable microbial count levels, the effectiveness of biological products will be reduced. Some compost can have very high levels. Levels can change quickly, i.e. over a 48-hour period, and are also dependent on the time of year.

Fungi: Bacteria ratio

A low fungi to high bacteria ratio will increase the incidence of grass weeds, while a high fungi to low bacteria ratio will decrease grass growth and encourage more complex woody weeds.

Weeds require a ratio of 0.1:1 while grass requires 0.75:1, vegetables approximately 3:1, vines and fruit trees 5:1, and forestry 100:1, although these may change as more research is undertaken in this field.

HOW CAN YOU CHANGE YOUR SOIL MICROBIOLOGY?

Manipulation of the soil biomass

Unfortunately soil biology cannot be manipulated quite like soil chemistry. One cannot apply a certain product and be almost sure of a certain outcome. However, this does not mean that we have no control over these levels. It may be a combination of many things that result in a change in the microbial population.

Nutrient levels in the soil can be balanced and improved to provide the soil microbes with enough nutrients to sustain growth of their colonies. Choice of product can also influence the soil microbes as well as quantities used. Nutrient requirements can be taken from the complete soil test.

Increasing the organic matter available in the soil will improve soil microbial levels and this can be done either by adding a product high in organic matter or changing management practices such as using mulching and leaving residues on the ground rather than removing them or by cultivating in a green crop, for example.

This project has been funded by Hort Innovation using the vegetable, fresh potato and potato processing research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Manipulation of the soil biomass (continued)

Products can be used directly to boost numbers. Soil inoculations of specific strains can be used to help fight diseases, or general microbe-based products can be used which boost general levels and can be tailored to build certain groups that are fungal or bacterial dominant. Such products include composts, compost teas, microbial metabolism products and other soil conditioners.

Products that are a food for soil microbes can also be used to boost levels. Fish fertilisers as a feed for fungi and molasses as a bacterial food source are good examples. There are also a number of commercial biological stimulants on the market.

The soil's physical environment can also be improved for instance via reducing tillage, strip tillage or drainage, compost and generally improving conditions for the soil microbes.

Areas that can be improved are aeration and water availability. Cover crops can also help protect the soil's surface from heat, cold or dehydration.

The reduction or better selection of pesticides, herbicides and fungicides can also help to maintain levels of soil microbes. The timing of these product applications can influence the effect that these products may have on soil microbes.

Contrary to popular belief, a single fungicide or pesticide application will not kill all soil microbes; however, sustained, poorly managed and programmed spray timetables will. The effect of chemicals can be minimised by applying products when needed through monitoring of pest and disease loading, application of biological stimulants and by applying higher amounts of microbial foods than may normally be needed.

A well balanced soil nutrient status will improve plant health, vigour and yield whilst reducing inputs and improving profitability. However, many chemical, physical and biological factors affect plant growth; therefore, regular monitoring is required to support good management.

CASE STUDY: SOIL MICROBIOLOGY TESTING IN TASMANIA

Over two years, soil microbial indicator tests were carried out on 265 paddocks in the Cradle Coast region and Northern Midlands of Tasmania. This was part of a project to monitor and implement farmer-based decisions for productive agriculture and sustainable land management. The main purpose was not on collecting data on soil microbiology. Still, the amount of soil microbiology testing data collected, lends itself to checking trends and differences between crops and regions.

The project was led by Doris Blaesing, then Project Manager at Serve-Ag Pty Ltd, and funded by the National Landcare Program.

Testing was undertaken to provide an indication of how biologically active the soil was, and understand the potential of the physical soil environment to support the growth of microbe populations. Testing included total and viable microbiological count, and separate counts for: aerobic and anaerobic bacteria, fungi, azotobacter and actinomycetes, as well as fungi:bacteria ratios.

The following crop groupings were analysed: pasture (73), potato (112) and cereals (barley, oats, rye, triticale and wheat – 32. The key findings are outlined on page 5.

Hort Innovation
ahr applied horticultural research
RMCG

This project has been funded by Hort Innovation using the vegetable, fresh potato and potato processing research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

FACT SHEET: SOIL MICROBIOLOGY
January 2021

Case study: Key findings

Differences in soil microbial levels between the Cradle Coast (mainly volcanic soils) and Northern Midlands (mainly duplex soils) regions were found. Bacteria levels under pasture were significantly greater in the Cradle Coast region than the Northern Midlands. This may have been due to the different soil types and crop rotations. In the Cradle Coast region, vegetables are a major part of rotations while pastures and grains dominate rotations in the Northern Midlands region.

Cereals had greater average total microbes, bacteria and fungi than pasture in both regions. Potatoes had the highest level of fungi compared to pasture and cereals. Total microbes under pasture peaked in the autumn-winter period. Under potatoes, there was little consistent seasonal trending and considerable variability in the total microbes with populations dominated by fungi.

What does it mean?

There was considerable variability in the data, as indicated by standard errors. Unfortunately, soil physical and chemical data was not collected at the same time as the soil microbiology data to provide insights into possible reasons for particular results or relationships to crop management and marketable yields. The results were considered in the knowledge that soil type, climate and crop type/rotation are all likely to influence the results.

The Cradle Coast region samples were all taken on Ferrosols (volcanic soils) with clay loam topsoil textures and relatively high organic carbon levels; the climate is cool temperate being near the coast and paddocks are irrigated. The Northern Midlands samples were dominated by duplex soils (Kurosols and Sodosols) with sandy loam topsoil textures, shallow topsoils and comparatively low organic carbon levels. The climate is both cooler in winter and warmer in summer than the Cradle Coast and few of the paddocks are irrigated.

While the soil microbial data provided information on some general trends, more supporting data on chemical and physical soil condition and crop performance would be required to better understand the benefit of certain microbial levels and ratios.

KEY MESSAGES

√ Soil microbiology testing can be used to see trends and differences between production conditions

√ Data needs to be collected over a longer timeframe to enable interpretation together with conventional soil testing data and assessment of soil structure

√ It is important to also monitor soil chemical and physical conditions at the time of sampling as well as crop rotation, inputs (e.g. nutrients, agrichemicals, water), tillage practices/ intensity, crop health and marketable yields.

REFERENCES

S Brake 2006, *DHM Labs (NZ) Ltd Soil Microbial Indicator Test – User Information.*

The Soil Wealth ICP team would also like to thank Ash Martin from Microbiology Laboratories Australia for his input and review into this fact sheet.