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Searching soils for functional genes

CSIRO Sustainable Ecosystems

A new soil test will examine the activity of genes in microbes to determine the efficiency of nutrient cycling. The test has potential applications across a range of agricultural and horticultural systems.

Soil organisms are increasingly recognised as vital to the health of agricultural systems. Bacteria, fungi, protozoa, insects and worms all play a role in nutrient cycling, disease and pest control, and 'structural maintenance'. But conventional crop-management practices can be their nemesis.

Artificial fertilisers and pesticides, tillage, soil compaction, and reduced rotations and fallow periods have upset the balance between good and bad soil organisms.

The addition of inorganic nitrogen further reduces the fungal component, creating a bacteria-dominant system ill-equipped to cycle nutrients and suppress disease.

Farmers worried about yield declines, recurrent disease or pest problems, or fertiliser and pesticide reliance can have soil samples analysed by a soil-testing laboratory.

These tests give farmers an idea of the number and balance of good and bad soil organisms. But they reveal nothing about the biological processes essential for proper soil functioning and plant growth, such as denitrification, ammonia oxidation and carbon mineralisation.

To answer this question, Dr Matt Colloff of CSIRO Entomology and Dr Steve Rogers of CSIRO Land and Water are developing a genetic test that looks at the presence and activity of microbial genes responsible for nutrient turnover in soil.

'Rather than looking at particular microbes in the soil, we're looking at the genes responsible for the function those microbes perform, such as nitrogen and carbon turnover,' Rogers says. 'And by looking at how active these genes are, we can determine whether nutrient turnover in the soil is working efficiently.'

For the past 18 months, Rogers and Colloff have been testing the technology on three soil types: a basaltic, tropical soil in Queensland, a red-brown soil in Victoria, and a sandy soil in Western Australia.

DNA is extracted from each soil sample using a commercial nucleic acid extraction kit. Then, using standard molecular biology techniques, the presence or absence of five nitrogen-processing genes and one carbon-processing gene is determined.

'We look for genes responsible for ammonia oxidation, nitrogen fixation and denitrification, and the gene for chitin breakdown, which is an analogue for carbon mineralisation,' Colloff says.

The activity of these genes is then determined by measuring the amount of messenger RNA (ribonucleic acid) in the soil sample. This molecule acts as a middle-man between a gene and its product (enzyme), giving scientists a direct link between the biology (gene) and biochemistry (enzyme activity) of a nutrient cycling process.

'If you can detect the presence of a gene, you know the organism that performs that function is present,' Colloff says. 'But until you look for mRNA, you won't know if the gene is active or not.'

To convert the test results into sustainable soil management practices, Rogers and Colloff aim to develop an 'intelligent management decision-support system'.

'If a soil sample has low ammonia oxidation activity, for example, we could suggest alternative practices that would build up the microbial populations responsible for this activity,' Rogers says.

Similarly, in the soils of Queensland sugar cane fields, Rogers and Colloff have identified active nitrogen-fixing populations that could be managed to enhance their biological potential, reducing the need for inorganic nitrogen fertiliser.

The test will be applicable across a range of soil types and agricultural management systems. This will allow development of a commercial test for soil-testing laboratories.

'This will be another tool in our tool kit to help understand, predict and manage landscape function and ensure that our landscapes are going to continue to function and be used sustainably,' Rogers says.

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