Managing crops to support favourable fungi

Beneficial fungi associated with roots help plants take up water and nutrients but their populations have been depleted in many agricultural soils because they are very vulnerable to disturbance from ploughing and other intensive farming techniques. Professor Jonathan Leake and colleagues investigated how well different wheat varieties supported beneficial fungi under different land-management techniques. They found that wheat genes interact with local environmental conditions to determine the abundance of beneficial fungi in the roots. Minimum-disturbance land management practices — including grass and clover leys in crop rotations — can boost their numbers and activity, improving soil structure and crop yield.

Introduction

Many plants harbour beneficial fungi inside their roots, known as mycorrhiza, which help plants take up nutrients and water efficiently, improve soil structure and boost plant growth.

However, there is concern that modern crop varieties do not create a supportive environment for mycorrhizal fungi, reducing their capacity to take up nutrients and maintain soil structure, preventing them from reaching their maximum potential yield.

To investigate the role of plant genes and land management on the abundance of these beneficial mycorrhizal fungi in the soil, Jonathan Leake (University of Sheffield) and colleagues compared strains of wheat, each harbouring different amounts of mycorrhizal fungi in their roots.

Methodology

The team cultivated genetically similar strains of wheat that had been selected for their differing capacity to harbour mycorrhizal fungi within their roots, using three cultivation types — conventional ploughing, reduced intensity tillage and direct drilling. They quantified the fungal communities present in the roots using microscopy and metagenomic analyses, and monitored soil structure.

The team trailed a well-established soil-improvement technique — a three-year grass-clover ley — on arable land that had been cropped and ploughed continuously for decades. The ley was treated with the herbicide glyphosate and the soil was direct-drilled with wheat to avoid harming the soil structure or disturbing mycorrhizae and earthworms that had developed as a result of the ley.

The BASICS

There are over 1.5 million species of soil fungi and they can make up between 55% and 89% of the total weight of microbial life in the soil.

Beneficial root-dwelling fungi called mycorrhizae grow in or on plant root cells and extend their hyphae out into the soil. They can form complex underground networks that help the plant take up water and nutrients, and hold the soil together in small ‘crumbs’.

Intensively managed soils tend to be low in mycorrhizal fungi, which are thought to be very sensitive to physical disturbance such as ploughing and to some herbicides.

KEY FINDINGS

- Direct drilling into a grass-clover ley increased the activity of beneficial fungi and lead to higher wheat yield than higher intensity cultivation approaches.
- Commercially available mycorrhizal inoculants had little effect on the fungi in wheat roots and in some cases actually decreased yield.
- Soil structure was improved beneath the ley — ley soils had a higher capacity to hold water and larger soil crumbs.

Wheat being harvested in the team’s experimental plots. The researchers found that direct drilling wheat into a grass-clover ley produced a higher yield than more intensive cultivation methods.
Results
The researchers found that after direct drilling their clover ley, they were able to produce a wheat yield of nearly 8 tonnes per hectare using just 35 kilograms of nitrogen fertiliser. “We built up the fertility in that soil using the ley to produce nearly national average yield with a fraction of the fertiliser and the crop grew extraordinarily well – it’s because the soil quality has been so improved”, said Leake.

Although the wheat lines used in the study had been selected for their differing levels of mycorrhizal fungi in Cambridge, when planted in fields in Yorkshire the differences were very minimal. The team says this shows that the influence of plant genetics on mycorrhizal communities is strongly influenced by the environment, making it more difficult to generalise from local results to general patterns.

Many cultivated fields are depleted of naturally occurring mycorrhizal fungi, so the team also trialled mycorrhizal inoculant to the soil to give fungal communities an added boost. Yet despite adding 205 kilograms of inoculum per hectare for 3 years, the team was unable to find a consistent beneficial effect on the mycorrhizal fungal communities. Counter-intuitively, those plots that did show greater numbers of mycorrhizal fungi as a result of the inoculum showed a slight decrease in yield.

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REDDER IMPLICATIONS

- Reducing soil disturbance improves crop productivity and promotes more active soil communities that are better able to resist environmental changes.
- Attempts to boost soil health using commercially available mycorrhizal inoculants may not be an effective strategy for intensively managed soils.
- Previous studies have suggested that the herbicide glyphosate is harmful to mycorrhizal fungi in the soil, but in this study, mycorrhizal fungi were more active and crop yields higher in unploughed leys treated with the herbicide.

“We have shown substantial improvements in soil biology and functions that benefit both farmers and society such as lower requirements for fertilizers and increased soil water infiltration and storage, which may reduce flood risks” - Jonathan Leake

Wheat yield attained from different cultivation types. Direct drilling allowed the full benefits of the ley to be realised, achieving national-average yield with a fraction of the fertiliser.