Multiple roles for soil fungi

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Healthy soil is a fundamental necessity for increased food production and may be a means of curbing atmospheric greenhouse gas (GHG).

Soil fungi and the highly beneficial relationship they can establish with host plants can make significant contributions to soil health.

Science has a good understanding of this relationship but in agricultural systems it has been often ignored in favour of reliance on application of fertilisers. This situation is changing, however, and a number of primary producers are inoculating crop seed with fungi spores to increase yields and improve soil condition.

Early observations of plant vigour, crop yield and cost reduction following seed inoculation with fungi appear positive, but these findings need to be scientifically confirmed. This potential notwithstanding, the most important characteristic of soil fungi may be its capacity to influence GHG-induced climate change.

GROWERS IN REGIONS INCLUDING S-W WA ARE EXPLORING THE POTENTIAL OF INOCULATING SEED WITH MYCORRHIZAL FUNGI TO INCREASE YIELDS AND IMPROVE SOIL CONDITION.

Analysis

Soil is fundamental to life. It provides food and is a central element in dealing with climate change. Only through its effective management will we be able to feed an increasing population and mitigate the impact of soil loss and nutrient degradation in agricultural soils.

To achieve these outcomes, we need to understand the relationships and mechanisms at play and implement measures that more effectively store and filter water and cycle appropriate nutrients, leading to greater and healthier growth of vegetation.

Until recently, the biological world has been considered in two parts: plants and animals. This was perhaps understandable as both were clearly visible. More recently, however, the scientific community has recognised several other components, including fungi, that are largely invisible but are where the greatest amount of biological activity occurs and where the largest diversity of genes and species reside. The relationships between these components are often complex but are vital and far-reaching.

We know that at least 80% – possibly more than 95% – of plants form mutually beneficial links with soil fungi. The most common fungi, which are linked to at least 90% of plants, are the mycorrhizal fungi. This relationship is well-researched and was known to the scientific community well before its discovery was attributed to a Polish botanist in the 1880s, but it has received little attention in modern agriculture. The general application of fungi-depleting fertilisers was perhaps seen as a more quantitatively reliable way of maintaining soil nutrition.

The relationship between mycorrhizal fungi and plants is highly significant but not essential. Once established, 10 to 40% of the carbohydrates, mostly sugars, produced by the plant during photosynthesis can be absorbed by mycorrhizal fungi. In turn, the long thread-like structure of the fungi acts as an extension of the plant's root system

KEY POINTS

- A beneficial relationship exists between certain soil fungi and many plants. This relationship is well understood, but has not been promoted by industrial agriculture.
- A growing group of primary producers are actively promoting the partnership between fungi and crops in order to promote soil health, increase production and reduce costs. Initial results have been positive, both in plant vitality and soil health.
- Soil fungi have the capacity to positively influence reductions in atmospheric greenhouse gases (GHGs). Soil fungi-promoted carbon sequestration could actively assist in combating climate change.

and increases the plant's access to essential nutrients, such as phosphorus, nitrogen, potassium, zinc and copper that would otherwise be available to the plant only when dissolved in water.

Soluble nutrients such as nitrogen and potassium can be accessed adequately by plants without the involvement of mycorrhizal fungi but less soluble nutrients are more difficult to acquire. Furthermore, the fungi provide these nutrients as they are required by the plant and will continue to promote plant health as long as there is an adequate supply of carbohydrates.

Plant root hairs extend one to two millimetres into the soil from a plant root. The fungi create an invisible network of threads that explore a much larger volume of soil, with threads extending 15 centimetres and beyond from the plant's roots. It is not uncommon for these networks of mycelial threads to extend for metres in depth from the host plant and cover hectares in area.

In addition to providing nutrients, this relationship between mycorrhizal fungi and plants provides other benefits to the plants including:

- Mycorrhizal fungi threads, or filaments, promote drought resistance in the partner plant by enhancing the water holding capacity of soil.

THE BARLEY HEAD ON THE LEFT IS FROM A CROP GROWN IN SOIL INOCULATED WITH MYCORRHIZAL FUNGI. THE ONE ON THE RIGHT IS FROM A CROP GROWN WITHOUT MYCORRHIZAL INOCULATION. (PHOTO CHRISTOPHER JOHNS)

INOCULATION WITH MYCORRHIZAL FUNGI IMPROVED ROOT GROWTH IN A FIELD COMPARISON OF CROPS GROWN WITH AND WITHOUT THE ADDITION OF THE FUNGI. THE BARLEY PLANT ON THE RIGHT WAS GROWN IN SOIL INOCULATED WITH MYCORRHIZAL FUNGI. THE ONE ON THE LEFT IS FROM SOIL THAT WAS NOT INOCULATED WITH THE FUNGI. (PHOTO CHRISTOPHER JOHNS)

- The outer walls of the filaments contain gluey compounds that cause fine particles of soil to clump together, building soil structure and making the ground less vulnerable to erosion.
- The fungi selectively exclude toxic elements, limiting the partner plant's exposure to heavy metals, such as lead and cadmium.
- At high latitudes, high altitudes and in rocky environments, mycorrhizal fungi dissolve and take up nutrients from primary rock surfaces.
- In boggy regions, the filaments buffer plant partners from the high acid content of peaty soils.
- In saline ground, the fungi can protect their partner plants from high salt concentrations.
- Mycorrhizal fungi can protect plants from pests, like nematodes, and diseases directly and by promoting plant vigour.

In many areas, the amount of soil fungi has been severely depleted due to farming practices such as extended periods of tillage, long periods of fallow and soil exposure to industrial substances. As a result, plants have become more dependent on added fertilisers and have become less efficient at using the nutrients provided in them.

Several agricultural practices will enhance fungi colonisation. Ideally, and wherever possible, the full range of critical soil health processes that govern productivity should be allowed to regenerate agricultural ecologies naturally. It may, however, be necessary or more practical to inoculate seed with fungi spores in order to speed the recovery of degraded soils.

Several farmers in the Great Southern agricultural region of Western Australia (south-western WA) are undertaking this course of action. Finding themselves confronted with an unsustainable spiral of ever-increasing commercial fertiliser costs and uneconomic or diminishing crop yields they decided a different approach needed to be taken and in recent years have inoculated seed with commercial fungi spores just prior to planting.

While it is still too early to provide statistically robust outcomes and, bearing in mind that there are no 'silver bullets' in agricultural production, the initial indications are that inoculation with mycorrhizal fungi is promoting improvements in crop vitality, yield and soil condition. In 2014, some of these producers compensated the cost of inoculation with a reduction in the rate of commercial fertiliser applied.

The capacity of mycorrhizal fungi to increase crop yields, improve the vitality of existing agricultural soils and to improve the productivity of soils that are currently marginal should be sufficient to generate major agricultural, commercial and scientific interest in increasing and managing populations of these fungi.

Their potential to positively influence future agricultural production may be unprecedented.

This assessment notwithstanding, the impact of mycorrhizal fungi on crop productivity could be of secondary significance.

In addition to promoting plant growth, which fixes more carbon into vegetation, mycorrhizal fungi can also, directly and indirectly, contribute to the stabilisation of carbon in soil. The fungi filaments have a carbon-rich component that can remain in the soil for decades and the fungus provides the first step for other soil fungi to convert plant waste into stable soil carbon.

Both these attributes have the potential to reduce atmospheric, carbon-based GHG.

Recent authoritative research on climate change has assessed that there is already too much GHG in the atmosphere. To halt and reverse the effects of human-induced climate change, GHG production must first be reduced and GHGs must then be drawn out of the atmosphere.

Plants, the nutrition of which can be enhanced by mycorrhizal fungi, have the capacity, if harnessed appropriately, to fix carbon back into the soil in sufficient volumes to make a significant contribution to efforts to combat climate change.

Summary

The agricultural future of Australia and the need to draw down GHGs and, thus, reduce their influence on climate change depend significantly on the health and vitality of soil.

Over the past 60 years, mycorrhizal fungi have been depleted from soils where industrial agricultural practices have undervalued their significance as one of the components of soil health. The development and application of practices that regenerate and promote the activity of mycorrhizal fungi in agricultural soils may be fundamental to a sustainable future.

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