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Agricultural Application of Mycorrhizal Fungi to Increase Crop Yields, Promote Soil Health and Combat Climate Change

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Key Points

- A beneficial relationship exists between certain soil fungi and many plants.
- The relationship is well understood, but has not been promoted by industrial agriculture.
- There is now a growing group of primary producers who 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.

Summary

Healthy soil is not only a fundamental necessity for increased food production, but may also be a means of curbing atmospheric greenhouse gas (GHG). A significant contributor to soil health is the presence of soil fungi and the highly beneficial relationship that they can establish with host plants. Science has a good understanding of this relationship but, in agricultural systems, it has been often ignored in favour of reliance upon the 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 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.

Analysis

Soil is fundamental to our life support. Not only does it provide food, but it 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 and then implement measures that more effectively store and filter water and cycle appropriate nutrients which, in turn, lead 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 a number of other components, including fungi, that are largely invisible but where the greatest amount of biological activity occurs and where the largest diversity of genes and species reside. The relationship between these components is often complex but is vital and far-reaching.

We know that at least 80 per cent – and, possibly, over 95 per cent – of plants form a mutually beneficial link with soil fungi. The most common fungi, which are linked to at least 90 per cent of plants, are the mycorrhizal fungi, pronounced *my-core-rise-uhl*. While this relationship is well-researched, and was actually known to the scientific community well before its discovery was attributed to a Polish botanist in the 1880s, 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 fungi and plant is highly significant, though not essential. Once established, ten to 40 per cent of the carbohydrates, mostly sugars, which the plant produces by 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 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 access adequately in this way, but less soluble nutrients are more difficult to acquire. Furthermore, the fungi provide these nutrients as they are required by the plant and, as long as there is an adequate supply of carbohydrates, they will continue to promote plant health.

While plant root hairs extend one to two millimetres into the soil from the root, the fungi create an invisible network of threads that explore a volume of soil extending 15 centimetres and beyond from the plant's roots, as depicted in Fig. 1, below. It is not uncommon for these networks of threads to extend for metres in depth from the host plant and to cover hectares in area.

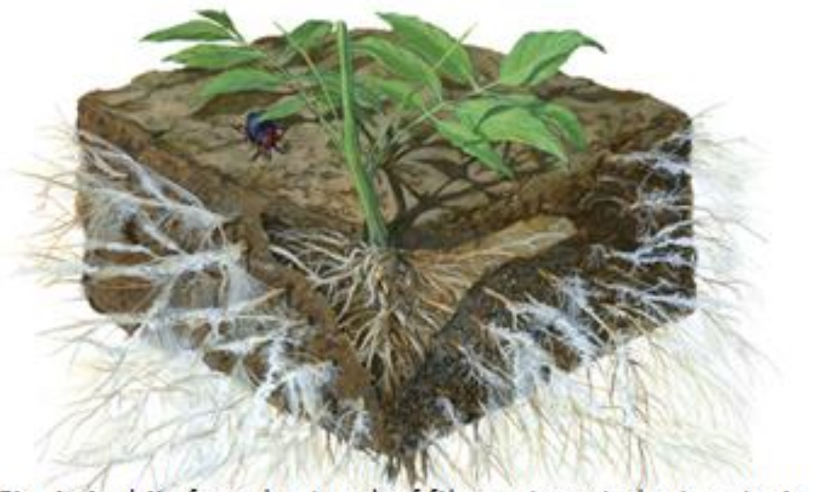

Fig. 1. A white fungal network of filaments, not plant roots, is the principal structure for the uptake of many important plant nutrients in the plant kingdom. *Illustration by Michael Rothman*.

In addition to the provision of nutrients, other benefits to the plant include:

- The mycorrhizal fungi threads, or filaments, promote drought resistance in the partner plant by enhancing the water holding capacity of soil.
- The outer walls of the filaments contain gluey compounds that cause fine particles of earth to clump together, building soil structure and making the ground less vulnerable to erosion.
- The fungi selectively exclude the passive uptake of toxic elements limiting the partner plant's exposure to heavy metals, such as lead and cadmium.
- At high latitudes, high altitudes and other 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 also protect plants from pests, like nematodes, and diseases both directly and by promoting plant vigour.

In many areas, the amount of soil fungi has been severely depleted due to certain 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 upon added fertilisers and have become less efficient at using them.

There are a number of agricultural practices that will enhance fungi colonisation. Wherever possible, of course, 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 recover degraded soils. A number of farmers in the Great Southern agricultural region of Western Australia 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, it was realised that a different approach need to be taken. In recent growing seasons, seed has been inoculated 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 indications are that mycorrhizal fungi is promoting improvements in crop vitality, yield and soil condition.

Fig. 2. Root growth variation in a barley crop sample from mycorrhizal fungi inoculated soil (left) compared with adjacent planting without mycorrhizal fungi inoculation (right).
Photograph by author.

This growing season, producers have compensated the cost of inoculation with a reduction in the application of commercial fertiliser. The results will be available later this year. Regardless of any outcomes, testing will require rigorous analysis and verification over several years. Future Directions International will make available post-harvest data once they have been fully analysed.

On its own, the capacity of mycorrhizal fungi to increase crop yields, to improve the vitality of existing agricultural soils and to make available currently marginal soils should be sufficient to generate major agricultural, commercial and scientific interest. The potential influence on future agricultural production may be unprecedented. This assessment notwithstanding, it could actually be of secondary significance.

Fig. 3. The same crop as depicted in Fig. 2, here comparing grain production in a plant from mycorrhizal fungi inoculated soil (left) compared with adjacent planting without mycorrhizal fungi inoculation (right). *Photograph by author.*

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

In summary, both the agricultural future of Australia and beyond, 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 last 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 their activity in agricultural soils may be fundamental to a sustainable future.

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Any opinions or views expressed in this paper are those of the individual author, unless stated to be those of Future Directions International.

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