THE ROLE OF ARBUSCULAR MYCORRHIZAL FUNGI IN SUSTAINING PLANT AND SOIL HEALTH

The term mycorrhiza is a combination of two Greek words: *myco* for ‘fungus’ and *rhiza* for ‘root’. The word refers to a mutualistic relationship that has developed between fungi and plants where the plant allows the fungus to grow within its roots and utilise the sugars and other carbon compounds that it produces by photosynthesis. In return, the fungus provides the plant with water and nutrients such as phosphorus, nitrogen, and trace elements.

Plants allow this ‘fungal invader’ to grow in their root system because the filamentous hyphal threads produced by the fungus are much thinner than the plant’s roots and can access pore spaces and niches that are inaccessible to root hairs and fine roots. Thus, the fungus enlarges the absorption area of its plant partner, thereby enhancing the capacity of the root system.

There are many different groups of mycorrhizal fungi but the most important in agriculture are the arbuscular mycorrhizal fungi (usually abbreviated AM fungi or AMF) (Fig 1 a, b). This group of fungi form close relationships with all agricultural crops except lupins, sugar beet, spinach, and crops in the cabbage family (e.g. canola, cabbage, cauliflower, broccoli and mustard). However, the benefits mycorrhizal crops obtain from this symbiotic relationship vary with plant species and the nutrient status of the soil. Thus, plants with poorly developed root systems and short root hairs gain the most from AM fungi, particularly when they are grown in soils that are low in phosphorus. Plants with extensive root systems and long root hairs (e.g. cereals) may also gain from the symbiosis, as AM fungi will sometimes deliver a large proportion of the phosphorus that is taken up by the crop. However, in highly fertilised situations, where plants provide the fungus with nutrients but gain no nutritional advantage from the association, AM fungi may have a negative impact on plant growth.

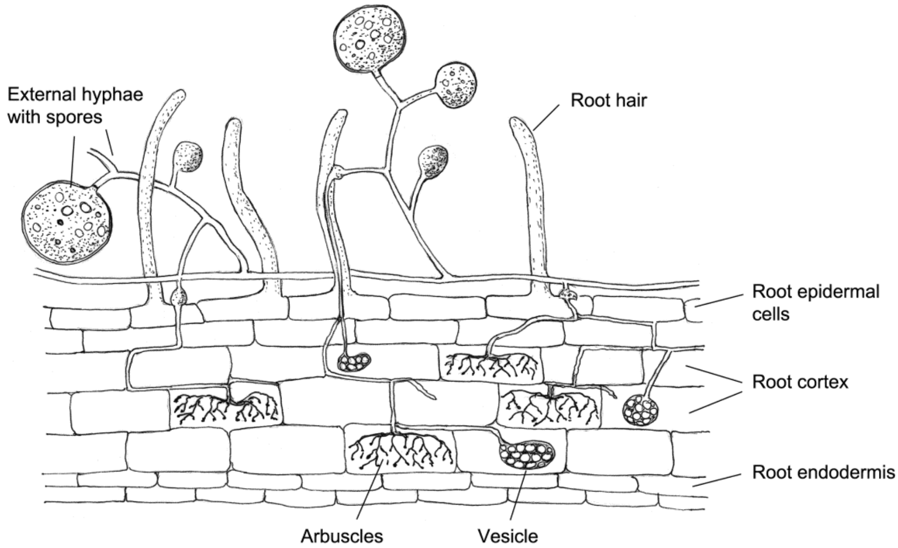

Fig. 1a. An arbuscular mycorrhizal fungus growing within a plant root. Although the fungus is growing within many of the cells, it is not causing any damage to the plant.

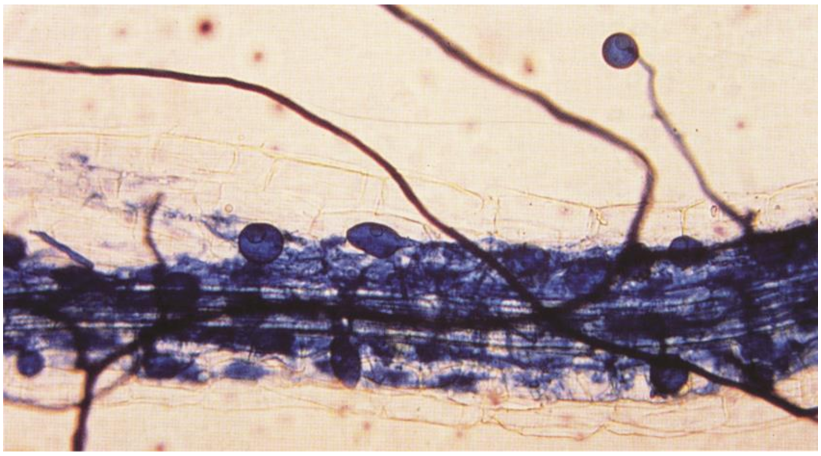

Fig. 1b. A plant root colonised by an arbuscular mycorrhizal fungus (stained blue).

AM fungi enable the root system to explore a greater volume of soil (Fig. 2) and this improves nutrient uptake. However, the symbiosis also provides other benefits.

- The hyphae of AM fungi, and the glomalin-related proteins they produce, help to improve soil structure by binding mineral particles into aggregates.
- Plants colonised by AM fungi are more drought-tolerant than non-mycorrhizal plants.
- The presence of AM fungi within roots induces a resistance response that results in the host plant being less susceptible to attack by soilborne pathogens and nematode pests.

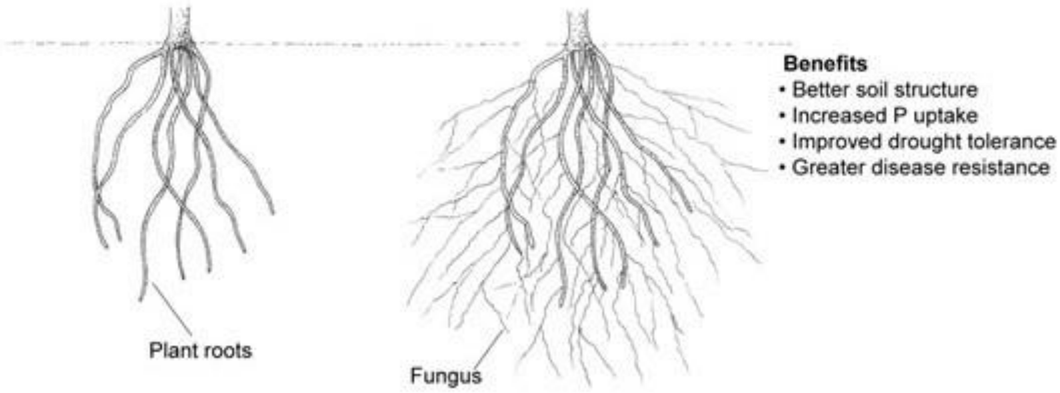

Fig. 2. Benefits arbuscular mycorrhizal fungi provide to a host plant

Australia is a country where crop growth is often constrained by dry conditions; where most soils do not have enough phosphorous for sustained crop and pasture production; and where soilborne pests and pathogens are a constant threat. Thus, one would assume that farmers would be encouraged to enhance the abundance and diversity of AM fungi in their soils. However, that is not always the case. For example, Ryan & Graham (2018) argued that there is no need to manage AM fungi because they have little impact on crop nutrition and productivity. I believe there are three problems with that contention and Rillig et al. (2019) agree. First, the authors focused on yield and ignored the fact that AM fungi improve soil structure, reduce nutrient losses, and provide other ecosystem services that are vital for the long-term sustainability of agroecosystems. Second, the claim of limited productivity benefits is potentially misleading because most of the field trials assessed in the agronomic literature are on cereal crops that do not always respond to colonisation by AM fungi due to their fine root systems. Third, the authors failed to recognise that the beneficial effects of AM fungi are probably underestimated in modern cropping systems because the abundance, diversity and colonisation potential of these fungi is constrained by a combination of management practices (e.g. the limited range of crops grown, regular fertiliser inputs, tillage, and agrochemical use).

Although Ryan & Graham (2018) argued that there is no need to manage AM fungi because of their limited impact on productivity, the results of a field trial with winter rotation crops in the northern grain growing region of Australian suggest otherwise. Canola reduced populations of *Pratylenchus thornei*, the most damaging nematode pest in the region, but in the following year, wheat yields were lowest following canola due to poor colonisation by AM fungi. The reason this occurred was that the season was dry (73 mm of in-season rainfall) and soil P concentrations were low, and in such situations, AM fungi provide yield benefits (Owen et al. 2010).

If you are a farmer who wants to improve rather than degrade your soil, I would argue that you should learn more about the invisible world beneath your feet. One way of doing this would be to submit soil or root samples to Microbiology Laboratories Australia (or another appropriate laboratory) and ask them to measure the abundance and diversity of AM fungi in your soil. Another option is to join the increasing number of farmers who are managing their soils in ways that allow mycorrhizae and other beneficial soil organisms to flourish. There are many practices that can be used to enhance mycorrhizal colonisation and improve soil biological health, but the most important are listed below.

- Maintain permanent ground cover by mulching and retaining crop residues
- Avoid or minimise tillage
- Enhance crop diversity with cover crops and a diverse rotation sequence
- Minimise compaction through traffic control
- Avoid high fertiliser inputs and minimise agrochemical use
- Integrate livestock and crop production

Although the practices listed above provide farmers with a range of management options, the actual practices that are integrated into a farming system will be influenced by the crops being grown, climatic factors, production goals and the economic realities of farming. Thus, it is impossible to be prescriptive about best-practice farming systems. Many potentially useful technologies and practices are available, and it is up to the land manager to adapt them to local conditions and constraints.

Literature cited and Further reading

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