The word 'mycorrhiza' is beginning to enter the language of greenkeeping. It now appears in several advertisements for companies selling biostimulant products. Here, I explain just what a mycorrhiza is, what it does, and what my research group at Royal Holloway is doing with it.

Myco what?

Orchids are totally dependent on their mycorrhiza for survival

Definition

The word 'mycorrhiza' (pronounced mike- o- riza) comes from the Greek and literally means 'fungus root'. It is a generic term, given to any intimate association between a fungus and the roots of a plant. It is important to realise that use of the word on its own means little; it as specific as using the word 'grass' to describe the species of plant growing in a golf green. Now, plenty of disease-causing fungi could also be said to form intimate associations with plant roots, yet they do not fall under the description of mycorrhiza. The thing that sets this fungus-plant association apart from all others is that both fungus and plant gain from the relationship. The scientific term used to describe such a relationship is mutualism. Clearly, in a plant-pathogen situation, there is no benefit for the plant and so it is not a mycorrhiza.

Myco what?

Types of mycorrhiza

A common misconception is that there is only one type of mycorrhiza, formed by one type of fungus with virtually any old plant. Nothing could be farther from the truth. In fact there are seven distinct types of mycorrhiza. Only four of these are at all common and of much relevance ecologically, and they are briefly outlined below. Another important point to realise is that the fungi which form any one type of mycorrhiza are taxonomically very different from those which form another type.

Orchid mycorrhizas

Everyone is probably familiar with the fact that orchids must have a fungus in their roots to enable them to grow. All orchids pass through a relatively long seedling stage, during which time they are unable to photosynthesise and thus cannot fix their own supply of carbon from the atmosphere. As a result, they are totally dependent on the mycorrhizal fungus in their roots, which supplies the plant with its entire carbohydrate need at this time. For most orchid species, the fungus continues to supply carbon and mineral nutrients to the plant, throughout its life.

Above: Heather depends on its mycorrhiza for growth in acidic, poor soils

Above right: Fly agaric toadstools are the fruiting bodies of an ectomycorrhiza, which associates with trees, not grasses

Ericoid mycorrhizas

As its name suggests, this type of mycorrhiza only associates with members of the Ericaceae, or heather family. The fungi grow in soils and when they encounter the roots of a plant of this family, they form an enveloping sheath over the tips. Some elements of the fungus from this sheath penetrate the roots of the plant. Inside there is an exchange of nutrients, with mineral nutrients moving from fungus to plant and carbon compounds moving from plant to fungus. It is thought that the presence of this mycorrhiza in soils allows heather to grow on acidic, nutrient poor soils. These soils have very low concentrations of essential nutrients such as nitrogen and phosphorus and if the fungus was absent, the plant root system is simply too inefficient at taking up sufficient quantities of these ions from the soil solution. However, the fungus is remarkably good at doing so, and the passing of these to the plant enables the plant to grow. There is a further added benefit of the fungus which is that it also has a remarkable ability to take up metal ions which would normally be toxic to the plant. Examples are aluminium and iron which become very soluble at low pH and could occur at levels high enough to kill the plant. The fungus takes up these metals and stores them, thus reducing their toxic effect on the plant.

Ectomycorrhizas

Ectomycorrhizas are very common. In fact virtually every woody plant forms an ectomycorrhizal association. As with the Ericoid association, the fungus envelops the roots of the plant, giving rise to its name (ecto meaning outside). The fungi which form these mycorrhizas can live perfectly happily without a plant, as they are decomposing organisms. This means it is possible to culture them in the laboratory. Most of the toadstools that you see in a woodland in autumn are the fruiting bodies of these fungi. A few produce their fruiting bodies below ground - these are the famous truffles. In autumn, turn over some leaf mould and you will see the strands of fungal mycelium (the 'roots' of the fungus) within. If some of this mycelium encounters the roots of a tree, then it forms the ectomycorrhiza, in which strands of the fungi penetrate the cells of the root. As with the Ericoid mycorrhiza, there is then an exchange of nutrients, with mineral nutrients (mainly nitrogen and phosphorus) moving from fungus to plant and carbon compounds moving the other way. Clearly, it is beneficial for the fungus to do this; it involves much less energy to obtain carbon from a host plant than it does to secrete enzymes which decompose leaves.

It is important to realise that these mushroom- or toadstool-forming fungi do not form mycorrhizal associations with turfgrass. This was brought home to me quite recently when I was walking a golf course with the greenkeeper. "Look", he said, pointing to some fly agaric toadstools, growing in the rough, "I've got mycorrhizal fungi - they're beneficial to the grass, aren't they?" I replied that the only thing they were benefiting was the silver birch tree we were standing beneath, and which, five minutes earlier, he had been complaining was growing too quickly!

Arbuscular mycorrhizas

From the turfgrass point of view, these are the important ones. On encountering the roots of a plant, the fungi do not form a coat or sheath, instead many individual strands of fungus (known as hyphae) penetrate the roots. These hyphae grow within the roots and inside the cells form structures which under a powerful microscope look like small Christmas trees, called arbuscules. These are the sites of nutrient exchange, with nitrogen and phosphorus moving to the plant and carbon compounds moving to the fungus. Unlike all the previous types of mycorrhiza, the fungi which form this association cannot obtain their carbon by decomposition. They are utterly dependent on the plant and so cannot be cultured on agar in a laboratory. Neither can you add carbon to the soil to feed these fungi. These fungi never produce toadstools, their spores are invisible to the naked eye and are formed in the soil. Arbuscular mycorrhizas are the type which associate

with grasses and herbs and therefore of importance to turfgrass. About 70% of the herbaceous plants of the world form an arbuscular mycorrhiza.

How arbuscular mycorrhizas benefit plants

Unlike the other mycorrhizal types, the arbuscular mycorrhizal (AM) fungi can confer a variety of benefits on a plant. These are:

- increased uptake of phosphorus
- increased uptake of nitrogen (nitrate and ammonium)
- increased trace mineral uptake, e.g. zinc and copper
- increased resistance to drought
- increased resistance to insect pests
- increased resistance to diseases

It is a common mistake to think that the only benefit to a plant is the uptake of P. This misconception has arisen because in all natural ecosystems, plants are limited by P availability, because this nutrient is immobile in soils. There are thousands of experiments which show that the AM fungus increases plant P uptake and therefore growth. However, in turfgrass, this is virtually irrelevant. Most turf soils have very high P levels and the plant can obtain its needs on its own. Therefore, in turf, the benefits of forming a mycorrhiza are mainly the last three items in the list above. I have found this misconception to be widespread; in fact some professional scientists have tried to tell me that AM fungi are irrelevant in turf, because they thought that P uptake was the only benefit conferred.

It is an interesting quirk that in the 30% of plants that do not regularly form an arbuscular mycorrhiza, the fungus may still try to enter the root. Sometimes it succeeds and is able to remove carbon, thereby acting as a parasite. When it does, plant growth is reduced.

AMfungi in turf grass

Research at Royal Holloway has found that the levels of AM fungi in turfgrass are much lower than in natural grasslands. An often cited reason for this is the amount of fungicide applied. However, in recent experiments, we could detect no short term effect of fungicides on the myconhiza in a golf green. There was a detrimental effect in a football pitch, though. The reason? The putting green had a well developed thatch layer, which was lacking in the football pitch. Thatch is a remarkably good biological filter and bacteria within it rapidly degrade the fungicide before it reaches the mycorrhiza in the root. Probably the main reason why mycorrhizal fungi are rare in fine turf is the amount of compaction this environment receives. We are continually being told that aeration is of the utmost importance for the health of the grass. It is also of importance for the health of the fungus. I and my students continually perform surveys of AM fungi in golf greens, to elucidate the factors which determine the occurrence of the mycorrhiza.

Our research has also revealed that the fungi appear to be able to reduce the growth of annual meadow grass. This grass happens to be one of the 30% of non-mycorrhizal species. If one grows Poa annua with a mycorrhiza then the growth of the plant is reduced. One of the major parts of our research programme is to find out the mechanism for this. However, this does add another unique benefit to mycorrhizas in turf - they have the potential to control the growth of this weed.

The future

The current situation is that we know that AM fungi are rare and sporadic in turf. We also have found that they can be inoculated into turf, resulting in better seedling establishment of bentgrass and reduced growth of Poa. We are currently investigating how effective they are in enhancing the disease resistance of grasses. There is much we need to learn about these strange fungi, but my prediction is that they will become one of the standard biostimulant products in years to come.