Getting to know the 'friendly fungi' associated with the roots of key timber species

Nadia Barsoum provides highlights of over 10 years of research shedding light on who's who in the world of friendly fungi colonising tree roots.

Beneath the forest floor, tree roots form an extensive, tangled network that becomes increasingly elaborate as it extends into the soil. However, this is not where a tree root system ends. Wrapped glove-like around most fine tree roots and extending from them are the thin thread-like hyphae of ectomycorrhizal fungi that can vastly increase the overall surface area of tree nutrient and water uptake. A gram of soil can contain hundreds to thousands of metres of these microscopic filaments which branch and explore between soil particles and bore into solid substrates such as wood.

Ectomycorrhizae (ECM) surround tree roots to form a mutually beneficial partnership with their host tree species, transferring water and essential minerals such as nitrogen and phosphorous to the tree host in exchange for sugars produced by the tree through the process of carbon capture from sunlight (photosynthesis). ECMs also produce chemicals (enzymes) which break down decaying material in soils, thereby increasing the supply of nutrients to trees.

Different ECM species excel in distinct specialist functions that trees depend on. These functions might include providing an effective physical barrier to protect roots either from root-eating predators (eg nematodes), soil toxins, desiccation during periods of drought and/or infection from disease-causing micro-organisms. Other specialist functions include the efficient decomposition of decaying organic matter to enhance nutrient supplies, the specialist uptake of specific nutrients, or the ability for long-distance exploration through soils. An individual tree would benefit therefore from having a diversity of ECM species on its roots to fulfil these multiple functions vital for tree health and growth.

Why research ectomycorrhizae?

While there is a growing appreciation of the value of ECMs to nutrient cycling in forest ecosystems and to tree health, there is a gap in our knowledge of the species that make up ECM communities in different forest types and the factors that influence woodland ECM communities. It is particularly important to gain an improved understanding of the community composition and dynamics of these 'friendly fungi' under present conditions of rapid global environmental change, when trees are encountering multiple stresses, including climate change, land use intensification, atmospheric pollution and emerging tree pests and diseases.

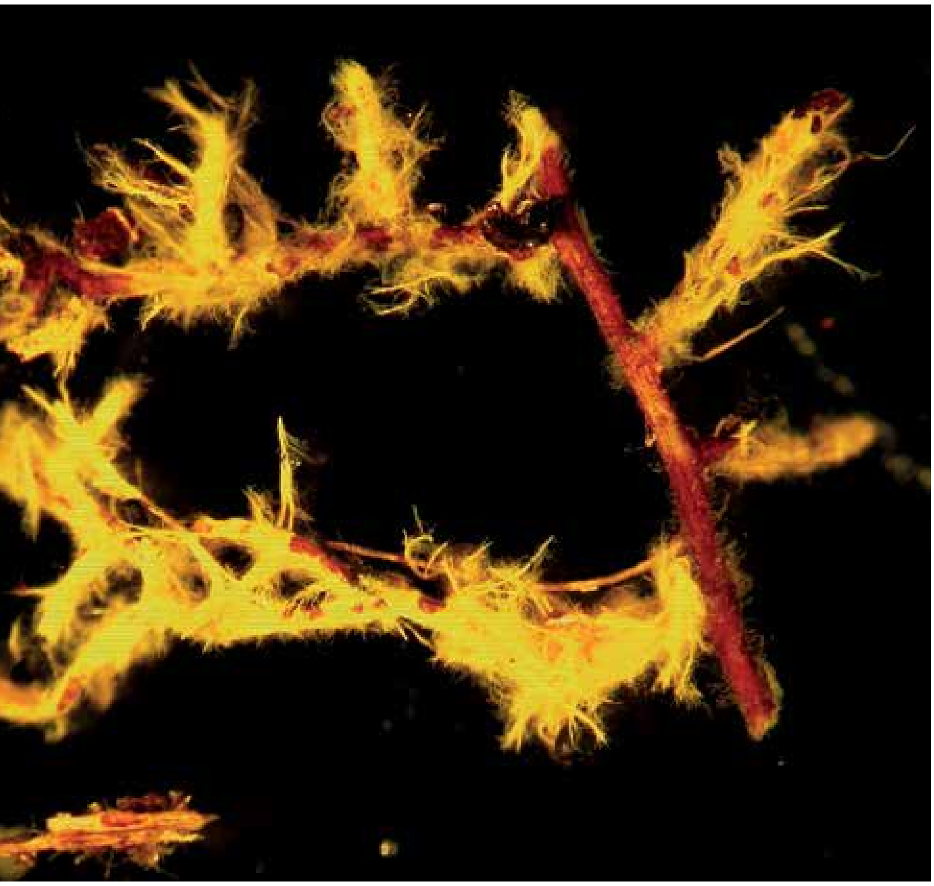
What research has been undertaken?

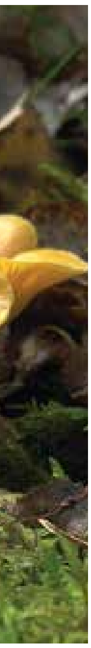
Early research on ECMs was hindered by the need for specialist taxonomic experts to identify ECM species present on either root tips, or on the sporadic above-ground occurrence of ECM fruiting bodies (eg mushrooms, crusts). In 2005, Forest Research initiated research into the large-scale study of ECM communities on timber species using novel molecular genetic techniques for ECM species identification. These molecular methods, applied in collaboration with Imperial College London and Kew Gardens, offer a significant improvement in the ability to identify ECM species and to determine the composition of ECM communities. Coupled with this, Forest Research promoted the use of a network of intensively monitored forest plots (ICP Forests Level II Network) for sampling ECMs.

The ICP Forests Level II Network comprises a Europe-wide network of forest plots, including conifer and broadleaf timber species such as (in the UK) Scots pine, Norway and Sitka spruce, beech and pedunculate and sessile oak. It provides a unique platform with which to:

- Explore relationships between the ECM species present and a wide range of environmental variables monitored at the plot level since the mid-1990s such as tree nutritional status (based on leaf chemistry), levels of soil acidity and atmospheric deposition of nitrogen (N) and potassium (K).
- Understand the degree to which different ECM species are host specific on conifers versus broadleaves or even particular tree species – host specificity is poorly understood and could be highly relevant in woodland restoration and afforestation contexts.
- Determine whether any observed patterns in the composition of ECM communities are site specific or occur repeatedly across a wide range of sites.

Over the last thirteen years, Dr N Barsoum (Forest Research) and Dr M Bidartondo (Imperial College London) have worked collaboratively to raise research funds which have resulted in a succession





1: ECM on Scots pine root tips. *Copyright Filipa Cox*
2 and 3: ECM fruiting bodies, such as these chanterelle *(Cantharellus cibarius)* and fly agaric mushrooms *(Amanita muscaria)*, are of limited reliability in ECM surveys since they do not accurately represent species abundances as not all ECMs produce fruiting bodies and the timing of fruiting body emergence can easily be missed.
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of related PhD and post-doctoral ECM research projects pursued in 137 Level II plots in 20 countries across Europe. By applying directly comparable sampling regimes and species identification methods, one important outcome of the combined research effort is the establishment of a valuable baseline dataset of the ECM communities associated with the following timber species in Europe: Scots pine, oak (pedunculate and sessile), beech and Norway spruce. This research is also building an understanding of the key variables that influence the ECM communities in European woodlands dominated by these tree species.

What has the research found?

The combined datasets reveal that the identity of the host tree species is important in dictating the occurrence of particular ECM species. Of the ECM species recorded, approximately 60% were found to be conifer or broadleaf specialists and 13% were only ever found in association with a single tree species. Temperature was another variable that had an important influence on ECM species distributions, indicating a preference by some ECMs for cooler or warmer conditions.

Another clear trend observed across the Europe-wide gradient is that N deposition, K deposition and soil pH strongly influence the number and types of ECM species present. ECM species diversity generally declines with increasing levels of both atmospheric N deposition and increasing soil acidity. The steep gradient in levels of N deposition across Level II plots in Europe permitted 'critical loads' to be set and used to highlight the point at which deposition levels become harmful for ECMs. For example, in oak-dominated woodlands, N critical loads of 17 kg N/ha/year result in dramatic changes in below-ground ECM communities including the loss of many ECMs with structures specialised in the long-distance transport of nutrients (eg Cortinarius species). Certain ECM species can also be used as indicators of levels of N deposition due to their particular sensitivity (e.g. *Lactarius chrysorrheus* – Yellowdrop Milkcap), or tolerance (eg *Scleroderma citrinum* – Common Earthball) to high levels of N deposition.

What next?

A decline in the abundance of ECMs compounded by a loss in ECM species and functional diversity can make ECM communities less resilient to environmental change. This in turn could have important consequences for tree host resilience to global environmental change. There is speculation, for example, that widespread reported observations of tree malnutrition across Europe may be influenced by a decline in ECM abundance and diversity which may be affecting the balance and acquisition rates of nutrients by trees. This link has yet to be proven, but underlines the urgent need for more research to clarify these relationships.

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