

Mycorrhizas

With a few notable exceptions such as the brassicas, most plant roots form close symbiotic associations with some specialised fungi. This combined structure formed by the fungus and the host plant's root is called a mycorrhiza (literally fungus root).

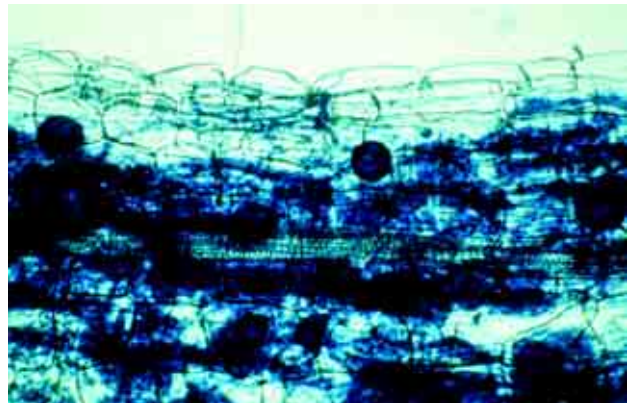
This relationship is generally beneficial to the plant because the fungus supplies it with minerals such as phosphorus from the soil. In exchange the plant provides the fungus with nutrients, such as carbohydrate, and a place to live. It is because of this close, often obligate relationship that plants raised in a sterile, high fertility, mycorrhiza free potting mix fail to survive after transplanting to an infertile situation such as your garden (Hall 1988).

Mycorrhizal relationships have been found in 460 million-year-old Ordovician fossils (Redecker et al. 2000). Since then the fungi have become very specialised so that most cannot survive unless they are in contact with their host plant. Many plants have also become equally dependent on mycorrhizal fungi and without them the plants become stunted and yellow, often due to a lack of phosphorus.

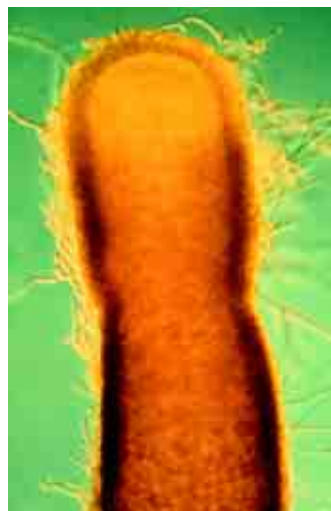
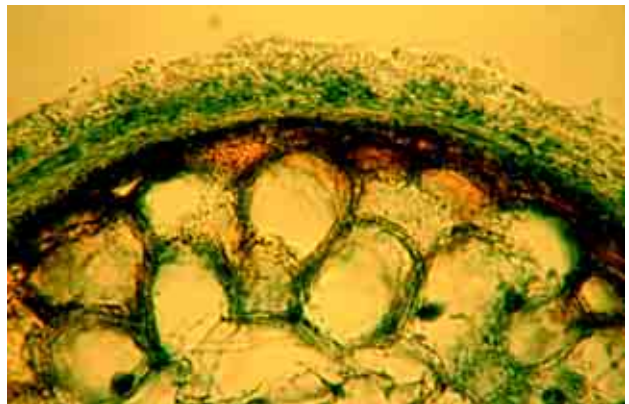
There are a number of types of mycorrhizas and, unfortunately, all have rather cumbersome names such as ectomycorrhiza, vesicular arbuscular mycorrhiza and ericaceous mycorrhiza. In an ectomycorrhiza, the fungus wraps itself all around the outside of the host plant's fine roots just like the fingers of a glove (Figure) while in arbuscular and ericaceous mycorrhizas, the fungus actually gets right inside the cells in the outer layers of the roots.

Most groups of plants form only one type of mycorrhiza on their root system. For example, rhododendrons and azaleas form only the ericaceous type of mycorrhiza, pasture species form vesicular arbuscular mycorrhizas and oaks form only ectomycorrhizas. While members of a plant family usually form only one type of mycorrhiza a few families have members that form either ectomycorrhiza or vesicular arbuscular mycorrhiza, for example, the Myrtaceae (eucalypts, manuka and pohutakawa) and Salicaceae (willows and poplars).

Each species of host plant is not restricted to just one mycorrhizal fungus. For example, Douglas fir can form mycorrhizas with hundreds of different mycorrhizal fungi. Similarly, some oaks can form ectomycorrhizas with a wide range of fungi, such as Caesar's mushroom (*Amanita caesarea*), the death cap (*Amanita phalloides*), porcini



A clover root stained with a blue dye to show the vesicular-arbuscular mycorrhiza inside.



With an ectomycorrhiza most of the fungus is on the surface of the root, just like the finger of a glove.

(*Boletus edulis*) as well as the Périgord black truffle (*Tuber melanosporum*), and it is not unusual to find half a dozen different ectomycorrhizal fungi competing for space on the roots of a suitable host.

Edible mycorrhizal mushrooms

Over the past 30 years or so there has been a broadening of the range of foods gracing the tables of our restaurants and the shelves of our delicatessens and supermarkets. Amongst these foods is an increasing range of specialty mushrooms. These alternatives to the common button mushroom can be grouped on the basis of their form of nutrition:

- saprobes, which grow on dead plant material and animal wastes, for example, button mushrooms (*Agaricus bisporus*, *Agaricus bitorquis*), shiitake (*Lentinula edodes*) and wood ears (*Auricularia* spp.),
- pathogens, which grow on living plants or occasionally animals, such as reishi (*Ganoderma* spp.) and vegetable caterpillars (*Cordyceps*),
- mycorrhizal mushrooms, which live in a symbiotic relationship on and in the roots of suitable host plants, such as the Périgord black truffle (*Tuber melanosporum*) and Italian white truffle (*Tuber magnatum*).

It is the cultivation of this third group which has captured the imaginations of scientists around the world, for some of these mushrooms, like the Italian white truffle, are among the most expensive foods in the world.

Cultivation of edible mycorrhizal mushrooms

About half of the world's species of edible mushrooms belong to the mycorrhizal group. Some of these are very expensive and have well established worldwide markets measured in billions of dollars.

All of the mycorrhizal mushrooms are seasonal, best eaten fresh and do not preserve well. Few of the Northern Hemisphere's commercially important species have made the accidental journey to the Southern Hemisphere. There is, therefore, a golden opportunity to introduce these species and produce the high value foods in New Zealand for out-of-season Northern Hemisphere markets—an idea that was first floated in the mid 1980s and is now the goal of Crop & Food Research's edible mushroom programme.

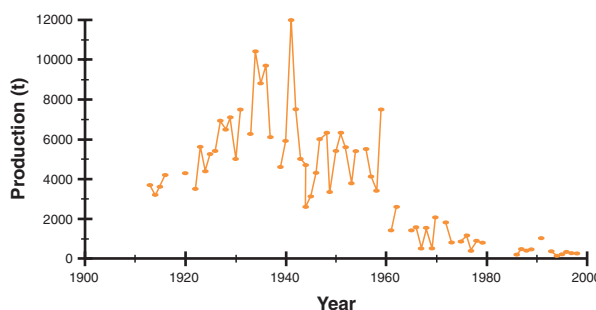
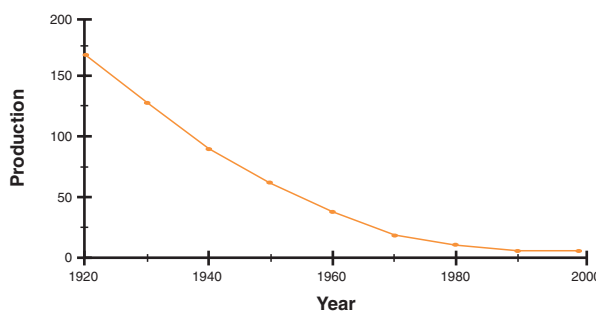
Of the 300 plus edible ectomycorrhizal mushrooms eaten around the world those held in the highest regard are the Périgord black truffle (Hall et al. 1994), Italian white truffle (Hall et al. 1998a), porcini (Hall et al. 1998b), chanterelle (*Cantharellus cibarius*; Danell 2001) and matsutake (*Tricholoma matsutake*; Wang et al. 1997). However, many of the 300 plus other edible mycorrhizal mushrooms like Caesar's mushroom (*Amanita caesaria*), honshimeji (*Lyophilum shimeji*), Burgundy truffle (*Tuber uncinatum*), Oregon white truffle (*Tuber gibbosum*) and saffron milk cap (*Lactarius deliciosus*) have significant local markets.



Mycorrhizas stimulate the growth of plants by transferring nutrients such as phosphorus from the soil to the plant. In this experiment clover has been grown in a sterilised soil and either infected with a vesicular mycorrhizal fungus (M) or left uninoculated (U).



The fly agaric (*Amanita muscaria*), which is very common in New Zealand, is an example of an ectomycorrhizal fungus that produces poisonous mushrooms.



Like the Périgord black truffle (*Tuber melanosporum*) and matsutake (*Tricholoma matsutake*), over the past 100 years there has been a catastrophic decline in the quantities of many mycorrhizal mushrooms that can be harvested from the wild.

Only a handful of the edible mycorrhizal mushrooms has ever been cultivated with any degree of success. Consequently, supplies are largely restricted to what can be harvested from the wild during the Northern Hemisphere autumn. Over the past 100 years there have been catastrophic declines in harvests of these species. For example, at the beginning of the 20th century, production of the Périgord black truffle has been estimated to have been between 1000 and 2000 tonnes, but now, even in a good year, production is rarely more than 150 tonnes (Lefevre and Hall 2000; Olivier 2000). The official figures for truffle production in Quercy, France, illustrate this trend well, as do those for matsutake harvests in Japan.

Because most of the ectomycorrhizal mushrooms of commerce are not found south of the equator, only fruit for short periods during the year, are best eaten fresh and do not preserve well, there is a golden opportunity to develop ways of cultivating these mushrooms in Southern Hemisphere countries to generate new markets in those countries and, more importantly, to satisfy the out-of-season demand in the Northern Hemisphere. There is also the possibility of expanding production in Northern Hemisphere countries to fill shortfalls.

The earliest cultivation of an edible ectomycorrhizal mushroom was achieved by Joseph Talon in the early 1980s (Hall et al. 1994; Hall & Wang 1998). He found, probably accidentally, that if he transplanted oak seedlings from the rooting zones of trees that produced Périgord black truffles eventually the new trees would also produce truffles. Despite its lack of sophistication, Talon's technique was widely used for 150 years. The main drawback with this technique is that seedlings are exposed to infection by all organisms in the rooting zone of the donor plant, such as insect pests, nematodes, and, perhaps worst of all, faster growing, contaminating ectomycorrhizal fungi such as species of *Scleroderma* as well as species of truffle like *Tuber maculatum* that have little commercial value.

These days all of the techniques that have been developed for infecting plants with edible mycorrhizal mushrooms begin by raising seedlings free of contaminating ectomycorrhizal fungi before infecting them with the fungus of choice. Because these techniques take many years to perfect they are jealously guarded by the companies that have developed them.

Further reading

- Danell, E. 2001: Current research on chanterelle cultivation in Sweden. Second international workshop on edible mycorrhizal mushrooms. [Http://www.crop.cri.nz/whats_on/mushroom_conf/Index.htm](http://www.crop.cri.nz/whats_on/mushroom_conf/Index.htm).
- Hall, I.R. 1988: Potential for exploiting vesicular-arbuscular mycorrhizas in agriculture. *In: Biotechnology in Agriculture*. Mizrahi, A. ed. *Advances in Biotechnological Processes*, volume 9. ARL, New York. Pp. 141-174.
- Hall, I.R.; Brown, G.; Byars, J. 1994: The black truffle: its history, uses and cultivation. Second Edition. New Zealand Institute for Crop & Food Research Limited, Christchurch, New Zealand.
- Hall, I.R.; Lyon, A.J.E.; Wang, Y.; Sinclair, L. 1998a: Ectomycorrhizal fungi with edible fruiting bodies. 2. *Boletus edulis*. *Economic Botany* 52: 44-56.
- Hall, I.R.; Zambonelli, A.; Primavera, F. 1998b: Ectomycorrhizal fungi with edible fruiting bodies. 3. *Tuber magnatum*. *Economic Botany* 52: 192-200.
- Hall, I.R.; Buchanan, P.; Wang, Y.; Cole, A.L.J. 1998c: Edible and poisonous mushrooms: an introduction. New Zealand Institute for Crop & Food Research Limited, Christchurch, New Zealand. 189 p.
- Hall, I.R.; Wang, Y. 1998: Methods for cultivating edible ectomycorrhizal mushrooms. *In: Mycorrhiza manual*. Varma, A. ed. Springer Laboratory Manual. Springer Verlag, Heidelberg. Pp. 99-114.
- Mycorrhiza information exchange. [Http://mycorrhiza.ag.utk.edu/](http://mycorrhiza.ag.utk.edu/)
- Lefevre, C.; Hall, I.R. 2000: The global status of truffle cultivation. *In: Fifth international congress on hazelnuts*. Corvallis, Oregon, August 2000. In press.
- Olivier, J.M. 2000: Progress in the cultivation of truffles. *In: Mushroom science XV: Science and cultivation of edible fungi*, Vol 2. Van Griensven, L.J.L.D. ed. Balkema, Rotterdam, Netherlands. Pp. 937-942.
- Redecker, D.; Kodner, R.; Graham, L.E. 2000: Glomalean fungi from the Ordovician. *Science* 289: 1920-1921.
- Wang, Y.; Hall, I.R.; Evans, L. 1997: Ectomycorrhizal fungi with edible fruiting bodies. 1. *Tricholoma matsutake* and allied fungi. *Economic Botany* 51: 311-327.