Mycorrhizae

As more and more is learned about how plants really work, it is becoming obvious that the conventional emphasis on soil chemistry and NPK fertilizers has problems - most notably in the areas of drinking water contamination, soil degradation, disease-prone plants, and input costs.

After decades of following chemically-oriented growing practices, soil scientists around the world are **now looking to the biological sciences** to find better, cleaner, and more sustainable methods of growing both crops and ornamentals.

What are Mycorrhizae?

In natural soil situations, plants enjoy **mutually-beneficial relationships and also dependence**, with many other organisms, many of them microscopic, and all these biological elements - plant roots, fungi, bacteria, and other life forms - play some role in the lives of the others. One party to this relationship is your tree, the other is a microscopic beneficial fungus. One type of fungus forms a sheath-like structure at the root tips, through which it passes to the tree various nutrients it has gathered from the soil, in exchange for food the tree has produced through photosynthesis (remember, fungi are not able to produce their own food in this way).

A plant that is colonized by mycorrhizal fungi can uptake as much as 100 times more nutrients. It is true that plants with inefficient root systems can be grown without mycorrhizal fungi, but they will require abnormal amounts of fertilizer. Although mycorrhizae are by no means essential to the well-being of any plant, their associations are of tremendous benefit in less than ideal circumstances. For example, a tree planted in fertile, moist yet well-drained soil with a good supply of readily available nutrients will already be growing at its maximum rate with maximum health, and so has little need of mycorrhizae. On the other hand, trees planted in marginal conditions would probably not survive without a mycorrhizae and it is in these conditions that mycorrhyzae will thrive. It is humanly impossible to duplicate the full range of macro, minor, and trace nutrients brought to a plant by mycorrhizae. Synthetic NPK “plant foods” can be lethal to beneficial soil organisms, which then creates an even greater plant dependence on human feedings for survival.

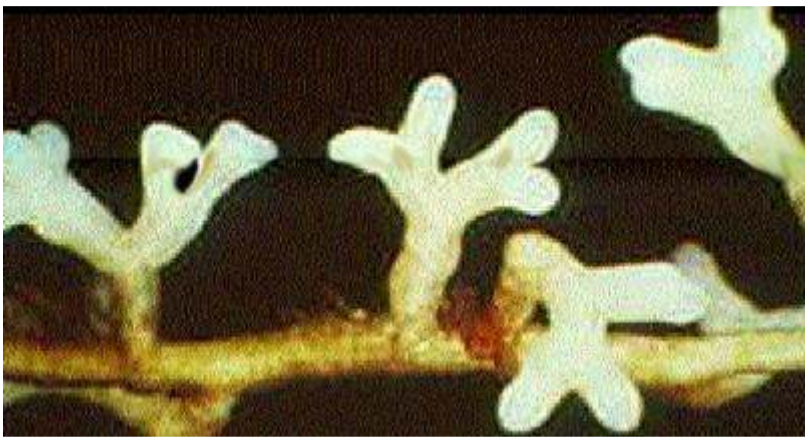
Is bonsai soil in a bonsai pot ideal or less than ideal?

Bonsai containers provide "marginal conditions" for any tree and it's only the dedication and knowledge of the grower that enables the tree to thrive. In a

bonsai pot the roots are subjected to the extremes of temperature - becoming as cold as the ambient temperature in winter and extremely hot in summer. They are also subjected to daily drenching and drying during the growing period. The soil has a large percentage of inert or lifeless material (dolomite, washed river sand, baked clay, grit, etc) and any nutrients are rapidly leached out with daily watering. These are exactly the conditions in which mycorrhizae can be of profound benefit to trees.

The addition of mycorrhizal fungi spores when repotting will ensure the presence of these valuable plant allies. **The difference in plant health and performance can be dramatic, especially when dealing with less-than-perfect soils.** Some extremely dependent plants, including grapes, citrus, melons, oaks and pines, may struggle to avoid starvation in soils that lack this helpful fungi.

With tillage and repotting, the network is disrupted but the fungi are not destroyed. If replacing of the fungi is done immediately, then the hyphae (fine, thread-like filaments) fragments can reestablish mycorrhizae.
When using biological methods, growers should expect slower growth in young seedlings during the stage when the beneficial fungi and bacteria are developing and colonizing the soil. This is a normal and natural difference between biological and chemical methods - nature works on a slower but much more powerful rhythm than do chemicals. Within a couple weeks time, the seedlings with mycorrhizae on their root systems will change appearance, then swiftly overtake and out-perform their chemically-forced cousins. The difference can be astonishing to nursery owners, especially when it involves “hard-to-propagate” types of plants.



Ectomycorrhiza on juniper roots

Are Mycorrhizae species-specific?

While there is very much left to be learned about these beneficial fungi, there is the opinion that they are far more soil-specific than plant-specific. Within a given soil ecosystem, the various plants are generally interlinked by the same

type(s) of fungi and become a community, rather than each plant hosting its “own” fungus partner.

There are a few mycorrhizal fungi species that will only associate with one host species such as Orchids, but the vast majority have a broad range of potential hosts. Likewise, virtually all plants - and almost certainly all trees - are perfectly happy to form mycorrhizal associations with a number of different fungi, the eventual choice being dictated largely by which fungi are available in those particular soil conditions.

A closer look

Types of Mycorrhiza

There are six kinds of mycorrhiza: **Endo**mycorrhiza, **Ecto**mycorrhiza, **Ectendo**mycorrhiza, Arbutoid, Monotropoid, Ericoid and Orchid. Of these six, there are two major types of mycorrhizal fungi based on the anatomy of their association with the host roots: **ecto**mycorrhizae and **endo**mycorrhizae. The group called Ectendomycorrhiza, combines some of the features of the Ecto and Endomycorrhizae groups.

An important fact about mycorrhizal fungi is that they are not all equal in the benefits supplied to plants. Some species deliver more benefits to plants than others.

Ectomycorrhizae typically grow in the outer layer of the root cortex, and forms a thick mantle of tissue around the exterior of the root tip. Some hyphae (fine, thread-like filaments) extend out from the roots and into the surrounding soil to gather water and nutrients. The network of intercellular filaments forms the exchange sites where the host swaps carbohydrates for nutrients from the fungus. Trees, such as oaks pines and juniper, match up with the Ecto type, while most others use Endo types.

Endomycorrhizae grow mainly inside the cortical cells of the root. These don't form any external mantle so they are impossible to detect with the naked eye, but they do also send out extensive hyphae into the surrounding soil. Some **endo**mycorrhizae form structures called vesicles and arbuscules within the root's cortical cells. These are known, naturally enough, as vesicular-arbuscular mycorrhizae, or VAM for short. This is the type of mycorrhizae we find on 90% of the world's higher plant groups. The VAM are tightly bunched hyphae, which take carbohydrates from the cells, growing as they do so. Once they have completely filled the cells, they break down, releasing their nutrients to the host and the fungus proceeds to colonize another cell. They contain abundant lipids and numerous nuclei and it is likely that they are important storage organs and may play a significant role within root fragments. Nevertheless, little is known of their biology, in particular with respect to either germination or mobilization of the reserves.

Reproduction

In all cases, germination is stimulated by near proximity of roots of a potential host plant, via their effect on the micro flora in the rhizosphere.

Benefits of Mycorrhizae

Research is continuing into the many benefits to plants of mycorrhizal associations and there are probably many yet to be discovered. However, in the light of current knowledge, benefits can be divided into six categories.

1. Water and Nutrient Uptake

Mycorrhizae greatly increases the roots efficiency at nutrient and water uptake largely because of the vastly increased absorptive surface area. The combined surface area of the millions of hyphae is far greater than that of non-mycorrhizal roots. Increased water uptake by mycorrhizal plants is due to physiological improvements which are made as a result of increased nutrient uptake into the plant. The water uptake is through the roots, not the mycorrhizal fungi. In addition, the extending hyphae are able to draw on more distant or inaccessible supplies of nutrients from hyphae than the roots can reach. (Bear in mind that the rhizosphere is always in effect nutrient deficient by virtue of the presence of the functioning root which has taken the available nutrients!)

Using radioactively-labeled nutrients, scientists have shown that **ecto**mycorrhizae are especially clever at absorbing phosphate and potassium as well as alkali metals. VAM were shown to be efficient at absorbing phosphorus, copper, iron, zinc and calcium. Potassium uptake by VAM is also indicated, but is governed by levels of nitrogen, potassium and calcium that are present.

2. Alleviation of Stress and Disease

Environmental and cultural stresses influence the plants susceptibility to, and ability to, combat bacterial diseases and are known to actually cause some non-bacterial diseases. VAM greatly reduce the environmental stresses - nutritional (too much or too little), drought, root pathogens, soil toxicity etc - which predispose a plant to disease. The increased uptake of nutrients, particularly micro-nutrients which are "locked" to soil particles and unavailable to the roots, make the plant less susceptible to the ingress of plant pathogens, and more resistant to other environmental stresses such as cold and heat.

3. Protection Against Root Pathogens

Ectomycorrhiza, in particular, have recently been shown to resist attack by soil-borne pathogens. For example, there are several mycorrhizal fungi known to protect pines from pathogens. There are several mechanisms by which this occurs, many of which are thought to operate simultaneously.

- production of antibiotics by the fungus itself, which inhibit root pathogens
- the physical barrier created by the mantle of **ecto**mycorrhizal hyphae

- production of chemical inhibitors by the host, induced by their reaction to invasion by the mycorrhizal fungus
- the establishment of populations of protective microbes in the rhizosphere.

4. Altered Root Physiology
Researchers have demonstrated that **ecto**mycorrhizae produce growth hormones and regulators which are responsible for the altered metabolism and growth of the roots themselves. These substances enhance the ramification of root tips, the proliferation of roots, enlargement of cells, and enhanced rooting of cuttings.

5. Detoxification of Soils
This is still a very sketchy area, as research is still in the early stages. However, scientists are now investigating what appears to be the capacity of mycorrhizae to assist plants to colonize soils which would otherwise be chemically toxic to the plants.

6. Maintenance of Soil Structure
Mycorrhizae accelerate the decomposition of primary minerals and secrete organic 'glue' (extra cellular polysaccharides) which bond the finer soil particles into larger, water-stable aggregates.

Mycorrhiza inoculation

We all save some old mycorrhiza from our pines, and re-introduce it into the new soil when we repot. Does this work? Well, yes it does.

In fact there could well be enough spores, and resting hyphae left on the remaining roots to colonize the pot ten times over. But because you have pruned away the root tips, where the mycorrhiza forms, and your loose, granular soil has left you with an almost bare-rooted tree, you can never be sure, so re-introducing it is a very good idea.

The same goes for other species with endomycorrhiza, which you can't see. Re-introducing chopped-up pieces of the pruned-away root tips will help to ensure re-colonization of the pot.

However, there is one other important point. Remember, that when the fragments or spores germinate, they are stimulated to do so by the microbial changes in the rhizosphere - which you don't have in your new soil and clean roots. The roots that the inoculated mycorrhizae is adhered to are now dead. One answer is to make sure that, when you introduce the chopped-up mycorrhizal roots, they are in good close contact with living FEEDER roots. Another is to include a proportion of the previous soil in your new mix. Since the entire pot was probably completely filled with roots, practically all the soil would qualify as rhizosphere.

Research has demonstrated that **endo**mycorrhizal fungi occurs naturally at low levels. For plants benefited by **endo**mycorrhizae, it can be more effective to apply a good commercial inoculum on an annual basis rather than trying to rely upon chopped-up mycorrhizal root fragments.

Mycorrhiza can also be highly dependent on the care you give your trees--too much water with soggy soil, too much fertilizer, antifungicide and pesticides, etc. can all play havoc with it.

OF INTEREST?

Talking trees?

There are instances where trees appear somehow to communicate with each other.

One involves a tree which is preyed upon by an insect which strips the tree bare faster than it can regenerate foliage, usually killing it. As soon as one tree in a cluster becomes infested, all the others immediately begin to secrete a substance toxic to the insects, thus keeping them away. Scientists now believe that the chemical message is passed through the mycorrhiza which commonly become bonded with mycorrhiza from neighboring trees.

Another involves a plant phenomenon called aggressive competition, where one species won't allow any other to grow near it. Researchers are now looking into the possibility that mycorrhizae are also responsible for this.

Some you can eat!

Although many mycorrhizae are microscopic, producing single spores, others produce quite large fruiting bodies. Miniature fungi that appear in the pots of birch, hornbeam, larch and spruce, may well belong to **ecto**mycorrhizal fungi. The most famous **ecto**mycorrhizal mushroom is the truffle. In nature animals feed on these and the spores pass through the body to be distributed around the forest as and when...!

Jurassic Mycorrhiza

Phyto-archaeologists have discovered correlations between the geologically sudden disappearance of tree species from large areas with the disappearance of evidence of associated mycorrhizae. The interesting aspect is that the mycorrhizae seems to have disappeared first, indicating the potential long-term effect of mycorrhizal deficiency.