

Trees and crops roots and fungi - a partnership for optimisation of agroforestry production in temperate climate

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Mycorrhiza is first and foremost a nutritious partnership between a fungus and a plant. In exchange, carbohydrates absorbed by the fungus from the root tissue of the plant, the plants, through the fungal hyphae, gain a better access to water and nutrients in the soil.

Mycorrhizal inoculation of plants can cause an increase in the productivity of crops by growth promotion, amelioration of environmental stress (drought, salinity, nutrient deficiency, heavy metals, adverse soil pH), biocontrol of pathogens (active and passive) and an improvement of plant foliar products quality of the host plants. Fungi increase diversity and stability of soil microorganisms. They also participate in the formation of soil structure (humus) due to the rapid decomposition of carbon from hyphae and the activities of glomalin and lipopolysaccharides that they produce.

Types of mycorrhizae and their role in agroforestry systems

Arable and post-arable soils have, in comparison to forest soils, distinct physiochemical properties as well as different sets of soil microorganisms, especially bacteria and fungi (Paul and Clark 1988). Arable soils are dominated by symbiotic endomycorrhizal fungi (hereafter referred to as **arbuscular mycorrhizal**. **Fig 1.**) that colonise the roots of nearly 90% of herbaceous plants: grasses, cereals, vegetables and root crops. Arbuscular symbiosis is present in some fruit-bearing woody plants and shrubs as well such as apple, cherry, walnut, poplar, willow, black locust, mulberry, ash, dogwood. Another popular type of symbiosis is **ericoid mycorrhiza** occurring in, for example, cranberry, blueberry, northern highbush blueberry and huckleberry.



Figure 1. Arbuscules inside the root cells, vesicles and hyphae of endomycorrhizal fungus in root tissue.



Figure 2. Extra-radical hyphae of ectomycorrhizal fungi in rhizosphere soil and on plant roots.

In arable soils, no trace of presence or activity of **ectomycorrhizal fungi** can be found (Cardon and Zoe 2011); these overwhelmingly tend to form symbiotic partnerships with broadleaved and coniferous trees. The presence of ectomycorrhiza on tree roots is manifested through characteristic shortened and thickened roots (Fig 2), and due to mushroom sporophores that appear under treetops. The above-mentioned types of mycorrhizal symbiosis (ectomycorrhizal fungi and arbuscular fungi) have similar functions with regard to various kinds of plants.

Tree ectomycorrhizal fungi increase resistance to root diseases (e.g. *Fomes annosus*, *Armillaria*), which improves plant health and survival of new plantings. Through stabilisation of the soil by the network of hyphae, ectomycorrhizal fungi increase the anti-erosive effects of tree roots. Mycorrhizal control of the production of plant foliar substances (e.g. salicylic acid in willow) can protect trees against insects and in this case provide a natural antibiotic to animals as well.

Trees associating with **arbuscular mycorrhizal fungi** (e.g. apple, cherry, walnut, poplar, willow, black locust, mulberry, ash, dogwood) may act as a reservoir for crops. Overall, mycorrhizal networks in agroforestry systems can allow trees and arable crops/grasses to communicate with each other and improve the exchange of water and nutrients.

Methods of introduction of mycorrhizal fungi in agroforestry systems

The best choice for new planting are trees that come from nurseries where they are frequently inoculated with ectomycorrhizal fungi (Fig 3.), or those which are subject to natural mycorrhization due to their location within forest complexes. Domestic tree species should be used, as they are ideally suited to the climatic zone of the designed agroforestry system. Mycorrhized seedlings, both bare root or cell grown, should be protected against desiccation. In the case of mycorrhization of cuttings, the mycorrhizal inoculant producer's instructions regarding the manner and timing of application of the preparation to the plant root system must be always followed.



Figure 3. Mycorrhized seedlings (on the right) are characterised by improved growth and development of root systems in the first year after planting.

The mycorrhization of cell grown seedlings should be performed by immersing it in the mycorrhizal suspension to the depth of $\frac{1}{2}$ the root ball and direct mechanical or manual planting.

Plants obtained as bare root seedlings should have their root systems evened out by trimming the roots that are too long, and then small batches of seedlings should be immersed in the mycorrhizal suspension and planted immediately.



Figure 4. Short Rotation Coppice willow combined with legume ley in an agroforestry system at Wakelyns Agroforestry, Suffolk, UK. Photo credit: Jo Smith

For the particular case of the mycorrhization of Short Rotation Coppice willow (Fig 4.), this may only be performed after each willow develops its own root system, about 2-3 months following planting. The application of the inoculant should be conducted using a two-hole application needle. It is essential that the temperature at the depth of 10 cm is not be below 12°C. The humidity of the soil should amount to 60% of water capacity.

Arbuscular Mycorrhizal Fungi inoculant in powder can be applied as an alternative to root inoculation by mixing with water and spraying onto the soil around the plant, by seed coating, or by water injection.

Arbuscular mycorrhizal is often combined with **Plant Growth Promotion Microorganisms** as a **bio-fertilizer**; however, the effectiveness of this solution is considered lower than for inoculated seedlings. With annual crops the biofertilizers can be distributed over the soil surface, alone or when sowing the seeds, or by in-furrow application. They can be also applied by directly treating the seeds with dusting, slurry or coating. In the case of application to already established orchards or plantations solid biofertilizer can be buried near the roots using a harrow-like device with injection by the distributor (Malusa and Ciesielski)

Careful matching of host plant, fungus and plant genotype is needed to obtain the best results. It is therefore of utmost importance to use regionally adapted fungus isolates.

Good practices favouring the development of plant mycorrhiza

- Intermediate level of N and low content of phosphorus in the soil (Liu 2000, Johnson 1993)
- Low or no soil disturbance (reduced tillage, conservation agriculture) (Galvez et al. 2001, Kabir 2005)
- Precision and sustainability of crop nutrition management (organic fertilizers/compost/ slow release fertilizers in reasonable amounts) (Douds et al. 2012, Ustuner et al. 2009)
- Diverse crop rotations (Larkin 2008) with cover crops and N₂-fixing legumes (Njeru et al. 2015), reducing plant families resistant to mycorrhizae (e.g. Brassicaceae, Chenopodiaceae, Linaceae) (Peat and Fitter 1993). Reduced application of chemical products (Miller and Jackson 1998, Carenho et al. 2000)
- Combination of arbuscular fungi inoculation with application of biofertilizers and biopesticides (Weber 2014)

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