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IFAS EXTENSION

Importance of Mycorrhizae for Agricultural Crops[1]

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What are Mycorrhizae?

The word *mycorrhizae* was first used by German researcher A.B. Frank in 1885, and originates from the Greek *mycos*, meaning 'fungus' and *rhiza*, meaning 'root'. Mycorrhiza is a symbiotic mutualistic relationship between special soil fungi and fine plant roots; it is neither the fungus nor the root, but rather the structure formed from these two partners. Since the association is mutualistic, both organisms benefit from the association. The fungus receives carbohydrates (sugars) and growth factors from the the plant, which in turn receives many benefits, including increased nutrient absorption. In this association, the fungus takes over the role of the plant's root hairs and acts as an extension of the root system.

Mycorrhizae are the *rule* in nature, not the exception. Most plants (more than 90% of all known species) present at least one type of mycorrhiza. Among important plants that associate with mycorrhizal fungi are corn, carrots, leek, potatoes, beans, soybeans, other legumes, tomatoes, peppers, onions, garlic, sunflower, strawberries, citrus, apples, peaches, grapes, cotton, coffee, tea, cocoa, sugarcane, forest species, wild plants, and even weeds. Cabbage, Cruciferae in general, and some aquatic plants are usually non-mycorrhizal.

Mycorrhizal Types

Two main types of mycorrhizae may be found, depending on whether the fungus penetrates into the root cells or not: *ectomycorrhizae* and *endomycorrhizae*.

Ectotrophic types, or e*ctomycorrhizae*, are found in roots of trees such as pines, birches, willows, and oaks. This type causes a drastic change in the root shape. The ectomycorrhizal fungus penetrates between the cell walls of the cortex and forms a covering sheath, or mantle, of fungal hyphae around the entire root. Ectomycorrhizae are short and forked and sometimes appear as tight clusters (Figure 1a, 1b). Most ectomycorrhizal fungi produce mushrooms (Figure 1c, 1d, 1e) and can be cultivated in culture media in the laboratory.

Endotrophic types, *endomycorrhizae* or *Arbuscular Mycorrhizae* (AM) do not form a mantle over the root, and the fungus actually enters the cortex cells. They are present in most agronomic and vegetable crops and fruits. This type is characterized by the presence of arbuscles in the region of the root

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Figure 1.b

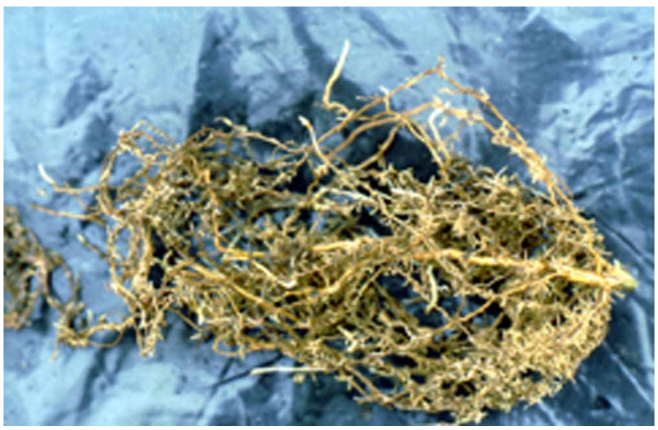

Figure 1.c

cortex; vesicles may or may not be present; and they may function as reserve organs and also for fungal multiplication. Arbuscles absorb nutrients from the plant cells but also release mineral elements to the plant. AM fungi also produce spores outside the root (Figure 2). Endomycorrhizal fungi have to be multiplied through a host plant. For this reason,

Figure 1.d

Figure 1.e

widespread inoculations are difficult and better field success is obtained through management of the symbiosis (i.e., nutrient conditions of the soil/substrate of plant growth).

Figure 1.f

Figure 1. Ectomycorrhizal roots of *Pinus* sp.(a) and *Eucalyptus* sp.(b). Note the dense fungal mass arond the roots and the bifurcated nature of this type of mycorrhiza, seen with the naked eye. Most ectomycorrhizal fungi produce mushrooms (c, d, e), in association with the host plant.

Figure 2.b

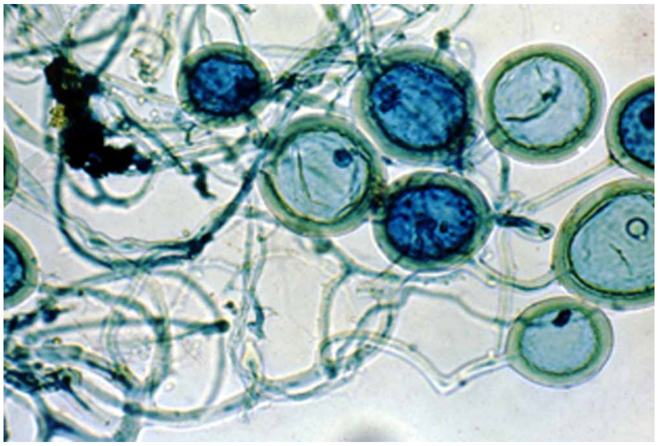

Figure 2.c

Plant Dependence on Arbuscular Mycorrhizae

Figure 2.d

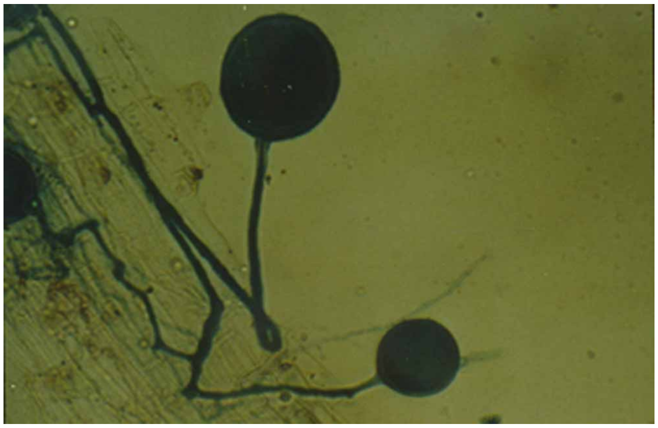

Figure 2.e

Figure 2. Endomycorrhizae or arbuscular mycorrhizae (AM) are characterized by structures formed in the root cortex region. (a) hyphae, vesicles and spores in soybean roots; (b) external spores; (c) cluster of auxiliary cells outside root; (d) external spores connected to internal cortex structures.

For some plant species, the association with mycorrhizal fungi is indispensable. The degree of dependence varies with plant species, particularly the root morphology, and conditions of soil and climate. Plants with thick roots, poorly branched and with few root hairs, are usually more dependent on mycorrhizae for normal growth and development. These species include onions, grapes, citrus, cassava, coffee, and tropical legumes. When the level of soil fertility and humidity are increased, the dependence on the mycorrhizal condition decreases to a point where the plant becomes immune to colonization.

Responses of Plants to Mycorrhizal Inoculations

The greatest plant responses have been obtained in fumigated/desinfested soils, where inoculation of plants such as citrus, coffee, and cassava become indispensable to good plant development. For avocado and citrus, seedling growth of non-mycorrhizal plants requires extremely high levels of readily-soluble P fertilizers. In non-mycorrhizal plants, the critical deficiency level of available soil P is 190 mg, compared with only 15 mg in mycorrhizal plants.

Under controlled conditions, with fumigated substrates, the beneficial effects of mycorrhizal inoculation upon plant growth can vary from zero to 2,600% in citrus and 1,000% in cassava, to cite a few examples. In field conditions and non-fumigated soil, these responses are of lesser magnitude but can reach 300%. The magnitude of response is unpredictable since it depends on factors that are inherent to the host plant, to the environment, and the fungus itself.

Beneficial Effects of AM

Beneficial effects of AM result from one or several of these mechanisms:

a) Increased overall absorption capacity of roots due to morphological and physiological changes in the plant. There is increased absorption surface area, greater soil area explored (since the fungus acts as an extension of the root) (Figure 3), greater longevity of absorbing roots, better utilization of low-availability nutrients, and better retention/storage of soluble nutrients, thus reducing reaction with soil colloids or leaching losses.

b) Increased mobilization and transfer of nutrients (P, N, S, micronutrients Cu, Zn) from the soil to the plant. Mycorrhizal fungi have been estimated to “substitute” up to 500 lb/a of P for citrus and 170 lb/a for soybeans in tropical areas.

c) Better development of P solubilizing bacteria in the myco-rhizosphere;

d) Increased establishment, nodulation and atmospheric nitrogen fixation capacity in legumes;

e) Modification of plant-pathogen relations: mycorrhizae influence the colonization of roots by other microorganisms, reduce the susceptibility (or increase the tolerance) of roots to soil-borne pathogens such as nematodes or phytopathogenic fungi such as *Fusarium oxysporum*, *Fusarium solani*, *Rhizoctonia solani* and *Macrophomina phaseolina*. Usually, plants of soybeans, cotton, tomato, oats, and cucumbers are less susceptible to nematode invasion when they are mycorrhizal. In studies with fungi such as Pythium, Phytophthora, Fusarium and Verticillium, in most cases (53%) the mycorrhizal interaction is beneficial for onions, cucumbers, and tomatoes.

f) Secretion of antibiotics and support of a community that competes or antagonizes pathogenic microorganisms, thus aiding in disease suppression;

g) Increased production of plant growth hormones such as cytokinins and gibberelins;

h) Modification of soil-plant-water relations, promoting better adaptation of plant to adverse environment conditions (drought, metals). At elevated heavy metal concentrations in soils, mycorrhizal fungi have been shown to detoxify the environment for plant growth.

Application of Mycorrhizae in Agriculture

Ectomycorrhizal inoculum is easily produced for application in forest nurseries, but the necessity of AM inoculum production via a host plant is still an obstacle to ample utilization of AM fungi in agricultural crops. Nevertheless, progress is being made in this area and some commercial inoculum is currently marketed in the US. Some of the important practical applications of mycorrhizae are a) in soil/substrate (including transplanting media) that are constantly fumigated or receiving high rates of fungicides to eliminate/reduce soil borne pathogens,

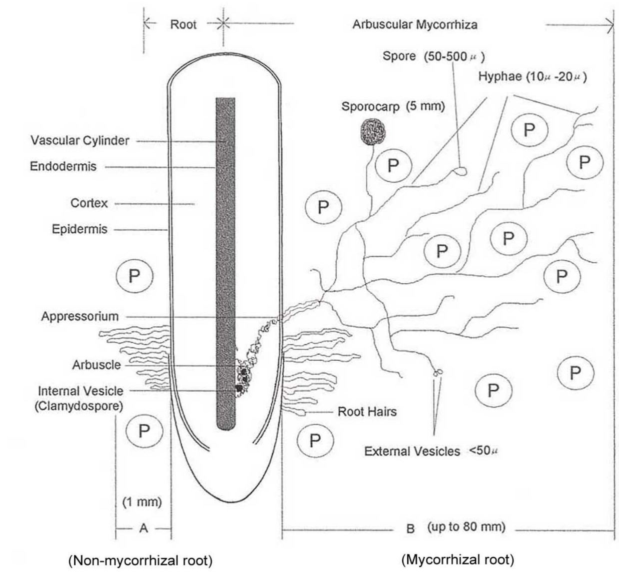

Figure 3. Schematic diagram of a root colonized by endomycorrhizal fungus. Note the zone of P (or other nutrient) absorption by a non-mycorrhizal root (A) and by a mycorrhizal root (B). P=phosphate ion.

such as in horticultural crops and fruits; b) in revegetation of eroded or mined areas (extreme pH; metal toxicity; low organic matter content, natural AM inoculum, and overall fertility); and c) in arid and semi-arid regions.

With increasing concerns about excessive nutrient application to the environment, the use of mycorrhizal symbioses to promote plant growth while reducing the inputs of fertilizer and pesticides may have great potential for citrus and vegetable crops, which respond very well to inoculation.