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MYCORRHIZAE BENEFICIAL SOIL FUNGI

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Vesicular arbuscular mycorrhizal fungi (VAM) are present worldwide in symbiotic association with most herbaceous crops and some trees. The fungi are provided with carbon from plant sugar and in exchange, the VAM supply the plant with inorganic phosphate (Pi), water and other elements.

Many soils throughout the world are P-deficient, and even in the more fertile soils, the Pi concentration of the soil solution is seldom higher than 10μM. In 135 representative U.S. soils, the Pi concentration of the soil solution was never higher than 8 μM, and the modal concentration was 1.5 μM. Low solubility of Pi salts is also responsible for the low concentrations of Pi in soil solutions, but it does not explain the complete unavailability of much of the Pi in clay soils. Possibly Pi becomes locked specifically into the crystal lattice of the mica surfaces. About 98-99% of Pi in clay soils can be bound so firmly that it cannot be extracted by salt solutions, exchanged with added Pi, or utilized by plants. A large part of soil P may be in the organic form; this is also largely insoluble, and the P may not be available to plants. Thus soil solutions typically contain 2 μM Pi while plants contain 5-20 μM Pi.

Existence of Pi depletion zones in the soil show that the roots have the potential for taking up Pi faster than can be supplied by diffusion. This may be so even in culture solutions. These usually contain 1-5 μM Pi, since these concentrations are optimal under static culture conditions and with limited solution volumes. When the effort has been made to grow plants in large volumes of flowing culture solution, the optimal Pi concentrations, 1-10 μM, are similar to those of soil solution. Finer roots with a larger surface area and greater length per unit weight should be able to draw Pi from a greater volume of soil and increase the uptake.

Mycorrhizal fungi increase nutrient uptake primarily by increasing the volume of soil explored. The significance of their value to agricultural crops is phenomonal, since the amount of plant tissue (roots) in the world infected by VAM species exceeds that infected by any other group of fungi. In addition to roots and soil, VAM fungi can be found sporulating in various weed seeds in the soil and may occupy vascular systems in the roots under certain conditions. Improved growth of plants with VAM infection has been obtained experimentally in soil, peat and sand, sand, and water culture.

Although VAM fungi are not plant species specific, certain species may be more effective in certain plants and even naturally tailored to be more beneficial in the roots of particular plant varieties. Characteristics that can be associated with species differences in their effectiveness at increasing nutrient uptake are: the ability to form extensive and well-distributed fungal strands (mycelium) in the soil, the ability to penetrate and invade newly formed roots, efficiency in absorption of phosphorus from soil solution, and time that hyphae remain effective in transporting nutrients to the plant. Various factors influence the infectivity and effectiveness of VAM fungi. Many examples are documented in the literature and contradictions are sometimes reported. In general, VAM fungi are most prevalent in plants grown in low fertility soils. A balanced high mineral nutrition may reduce the degree of ectotrophic infection, whereas a low or unbalanced nutrient supply may increase it. High light intensity of a moderate deficiency of either available nitrogen or phosphorus increases the amount of carbohydrates in the roots and makes them more susceptible to mycorrhizal infection. Foliar application of Pi inhibited VAM infection of onion, demonstrating that Pi concentration in the host plays an important role. Nitrogen, complete fertilizer, and bacterial fertilizer can also reduce mycorrhizal infection in the field. Small additions of nutrients to very nutrient-deficient soils or media can, however, increase infection both in field and pot experiments. Water relationships are important. Mycorrhizal Ipomoea carnea plants growing on drier soils become non-mycorrhizal when temporarily waterlogged during the monsoon season, suggesting that wet growing conditions result in the absence of mycorrhizae.

Differences in N, K, Ca, Na, Mg, Fe, Cu, B, Zn, and Al concentrations of mycorrhizal and non-mycorrhizal plants have been reported. Results are, however, inconsistent with the possibly exception of copper, which generally reaches greater concentrations in mycorrhizal plants, and manganese, which is generally lower.

Mycorrhizal spores and spore types vary with different soils. In New Zealand and Australia soil-borne (extra-matrical) spores and spore types were generally more numerous and varied in cultivated than in non-cultivated soils. In West Pakistan certain spore types were more common in northern and mid-northern areas where soils are sandy. In six Nigerian areas with differing vegetation types, spores tended to be more numerous in the arid savannahs than in the moist forests, but some fluctuations and unexpected variations occurred in adjacent sites. Most of the spores occurred in the top 15 cm. Spore counts changed little from December until June, increased significantly in July, and decreased again slowly from September until December. Fewest spores were found in April and most in September in a Molinietum corerulae association.

Prolonged fertilizer applications may cause changes in numbers and composition of the spore population in some soils. In one report, in a sandy soil that had grown rye and potatoes for 50 years, unfertilized plots contained few spores, and numbers increased progressively in plots fertilized with NPK, farmyard manure, leaf mold, and farmyard manure plus NPK. However, on a heavy clay soil where wheat had been grown for over a hundred years, fertilizers had the opposite effect. In onion fields, both root infection and mycorrhizal spore numbers in the soil were negatively correlated with added Pi. Onion bulb weight and mycorrhizal spore number at harvest increased when mycorrhizal inoculum was added to the soil. In the soil that was high in available Pi (97 kg/ha), bulb weight, root infection, and spore numbers were not influenced by added Pi or added mycorrhizal inoculum. Root infection data from both soils suggested a threshold level of soil Pi below which mycorrhizal infection was high and above which infection was low. The levels of P commonly added to muck soils may negate any usefulness of mycorrhizae but addition of Pi might be reduced if mycorrhizal spore numbers are increased through inputs of mycorrhizal inoculum or cultural practices.

Both reduction and increase of mycorrhizal propagules (spores and spore types) in the soil due to fumigation practices have been reported. Fumigation of nematode-infested field soils with nematicidally active rates of 1,2-dibromo-3-chloropropane (DBCP), and related C_3 hydrocarbons, resulted in significant increases in endomycorrhizal infection of cotton roots. No endomycorrhizal fungi were observed in cotton roots grown in methyl bromide-treated soils. Stunting and chlorosis of citrus and Rosa multiflora in fumigated or heat-treated soils have been previously attributed to soil toxicity. Evidence indicates the major cause of this problem may be inadequate nutrition brought about by the killing of mycorrhizal fungi. Glomus fasciculatum and G. constrictus (two common VAM) are both more sensitive to methyl bromide fumigation than most soilborne plane pathogens. Furthermore, VAM fungi can readily be destroyed by methyl bromide fumigation in the top 45 cm of soil by most commercial methyl bromide fumigations.

Joint inoculations with mycorrhizal fungi and root knot nematode (Meliodogyne incognita) resulted in nullification of stunting of cotton caused by the nematode alone. This effect was attributed to the development of and protection afforded by the mycorrhizal fungi. Ethylene dibromide proved to be more effective than methyl bromide against root knot nematodes and is recommended for use in this capacity. It also is more effective than methyl bromide in the promotion, either directly or indirectly, of a more rapid and luxuriant growth of stem, leaves, and root. Methyl bromide also proved to be much more effective in suppressing a wider range of fungi than either ethylene dibromide or 50% 1,3-dichloropropene mixture.

Methyl bromide vaporizes rapidly in the soil and escapes through the covering polyethylene tarps. Deep penetration, therefore, only occurs in very porous soils. Evidence indicates that most field fumigations are capable of eliminating VAM fungi from the soil. However, crop stunting does not occur on the majority of fumigated sites; instead growth of crops is usually stimulated by fumigation. This apparent anomaly can be rationalized by a careful look at data from MB fumigations, many of which are carried out under optimum conditions, indicating that VA mycorrhizal populations are not always reduced by MB. Rarely, if ever, are fungi completely eliminated by fumigants, as evidenced by the characteristic patches of healthy plants scattered among the stunted ones in fumigated fields. Many factors affect the efficiency of fumigations, such as temperature, moisture, soil texture, tarping, and organic matter.

The complicated nature of the soil and biosphere is becoming increasingly evident. Research is needed to outline specific procedures for effectively utilizing these beneficial fungi in our cropping systems.