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## Plant-Fungal Symbiosis

The current era of deforestation and consequent soil erosion in many countries must ultimately be followed by reforestation. In much of the tropics, the growth of food crops or forests is limited by low availability of phosphate in lateritic soils. The growth of vegetation can be substantially increased by the presence of symbiotic fungi. The benefits of the relation can include enhanced efficiency of uptake of phosphate, drought tolerance, broader pH tolerance, and resistance to certain pathogens. The fungi attach to roots and send out hyphae that increase the volume of soil tapped by the tree or plant. The value of the symbiotic relation has been shown on strip-mine sites: seedlings with symbionts prospered while control seedlings languished or died.

Many woody plants have ectomycorrhizal fungi as their symbionts. This group of fungi forms myceliums that surround the roots. Techniques are available to grow the myceliums of these fungi in pure culture. A commercial venture, Sylvan Spawn, of Butler, Pennsylvania, now is able to supply large amounts of fungi prepared from a customer's isolate. Millions of pine seedlings are already being treated, and the cost per seedling is only about one cent. Benefits include better performance of the seedling in the nursery and better survival and growth in the field. Ultimately a substantial fraction of the 2 billion tree seedlings set out annually in the United States may be treated. The seedlings are obtained from seeds planted in fumigated soil to which the inoculum is added. These procedures are in the process of being mechanized.

When the seedlings and their symbionts leave the favorable environment of the nursery, they enter what may be a hostile circumstance. Thus it is necessary to determine what combination of tree and fungus can best cope with each new environment. Fortunately, some species of the fungi have broad capabilities of associations with trees and of flourishing in a broad spectrum of environments. An example is a culture of *Pisolithus tinctorius* that was selected and is maintained by D. H. Marx of the Department of Agriculture Forest Service Laboratory in Athens, Georgia.

The symbionts of most food crops and some trees invade the roots, resulting in combinations called vesicular-arbuscular mycorrhizae (VAM). They also act to extend the volume tapped by the plants. About 80 percent of all the plants and trees have VAM symbionts. In the United States VAM has been tested with vegetable and fruit crops. Benefits have been demonstrated with many plants and trees including citrus, sweet gum, and black walnut. Legumes with VAM tend to be better nodulated than those without VAM in soils low in available phosphorus. Considerable research has been devoted to tests of VAM with grain crops. However, application of large amounts of fertilizers produces yields more inexpensively than does the application of VAM. One factor limiting the practical use of VAM is that it has not been possible to grow VAM in pure culture. Another limitation is the poor response of the plant-symbiont relation to substantial levels of available phosphorus. In these circumstances the mycorrhizal fungi do not benefit the plant or may be absent.

Half the land in the tropics has soil poor in available phosphorus, and is thus unfit for agriculture without application of large amounts of phosphate. The use of VAM could reduce the need. Additional cropland could be made available by the use of VAM to increase the salt tolerance and drought resistance of plants.

Further improvement of relation between trees, symbionts, and their environments is likely to take two forms. The potentials for improvement through conventional selection procedures have not been exhausted. In addition, strenuous efforts are being made to improve plants through genetic engineering techniques. These efforts will surely come to include a broad approach to plants and trees that treats them and their symbionts as a system to be optimized.—PHILIP H. ABELSON