Interactions of nematodes with mycorrhizae and mycorrhizal fungi

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Plant-parasitic nematodes often encounter roots that have been transformed structurally and physiologically by mycorrhizal fungi. These symbiotic associations of fungi with higher plants are broadly termed mycorrhizae (or mycorrhizas, sing., mycorrhiza; the literal translation is ‘fungus root’). The fungal partner obtains carbon compounds from the plant and the plant partner effectively extends its root volume, thereby improving its access to possibly scarce inorganic soil nutrients, especially phosphorus, and soil moisture. The interaction of nematodes and these beneficial symbionts is unlike those between parasitic nematodes and pathogenic organisms that are described in other chapters of this book.

9.1 MYCORRHIZAE AND MYCORRHIZAL FUNGI

Mycorrhizae are a diverse group that have been classified according to structures formed in the root and families of plants that are infected. The two most widespread and important groups are the ectomycorrhiza and the endomycorrhiza. An intermediate form, the ectendomycorrhiza, has been described and endomycorrhizae can be further classified into vesicular-arbuscular, ericoid and orchid mycorrhizae, with the latter two occurring in association with the Ericaceae and Orchidaceae (Harley and Smith, 1983). One should be careful to make the distinction between the fungi that cause mycorrhiza to form and the mycorrhiza itself. This chapter will concentrate upon interactions of nematodes with ectomycorrhizae, vesicular-arbuscular endomycorrhizae and the fungal symbionts, after an introduction to mycorrhizal biology.

Virtually all plants infected by ectomycorrhizal fungi are woody perennials. Most are temperate forest species, such as members of the Pinaceae, Fagaceae and Betulaceae, but there are important tropical families represented as well, such as the Dipterocarpaceae. Ectomycorrhizal fungi are
predominantly higher Basidiomycetes and reproduce by forming the familiar fleshy fruiting structures. A few taxa in the Ascomycetes and Zygomycetes are also represented to a lesser extent (Harley and Smith, 1983). Ectomycorrhizal fungi promote rapid seedling growth and have been found to be essential to produce woody perennials economically in nurseries (Wilde, 1954; Maronek et al., 1981; Kropp and Langlois, 1990). Thus, in fumigated soils and areas previously devoid of ectomycorrhizal tree species, there is an impetus to inoculate soils with ectomycorrhizal fungi for increased productivity.

Ectomycorrhizal fungi penetrate juvenile roots and develop a hyphal network called a Hartig net in the middle lamellae between root epidermal and cortical cells. Eventually, a sheath or mantle of fungal tissue, which is interconnected with the Hartig net, surrounds the exterior of the root. There is apparently little or no penetration of plant cells by the hyphae. The ectomycorrhizae are typically stubby in appearance and as such are distinctly different morphologically from uninfected roots.

Endomycorrhizae that form vesicles and arbuscules within roots are commonly called VAM fungi. Hyphae grow within the root cortex (inter- and intracellularly) and arbuscules penetrate cortical cell walls and interface with the cell's plasma membrane, much like haustoria of obligately parasitic fungal species (Brown and King, 1987). In fact, VAM fungi have yet to be cultured away from their host (Hepper, 1987). Arbuscules are regarded as the primary avenue of bidirectional transfer of materials between the two symbionts. Vesicles are globose to irregularly shaped and contain large amounts of lipid (Holley and Peterson, 1979). Vesicular-arbuscular mycorrhizae are usually similar in appearance to uninfected roots, so histological preparation is necessary to observe the internal morphological structures. Sometimes the size and density of vesicles are great enough in older roots that the mycorrhizae take on an uneven, torose appearance.

Most families of Angiospermae contain species that are symbionts with VAM fungi. The economically important exceptions occur in the Chenopodiaceae and Brassicaceae. Vesicular-arbuscular endomycorrhizal fungi form symbiotic associations with many woody perennial species not colonized by ectomycorrhizae, including many gymnosperms outside the Pinaceae (Harley and Smith, 1983). Both tropical and temperate forests have a high incidence of infection by VAM fungi (Baylis, 1961; Alwis and Abeybayake, 1980; Thapar and Khan, 1985). Vesicular-arbuscular mycorrhizal fungi are classified as Zygomycetes in the family Endogonaceae. Taxonomic placement into species is involved because most, if not all, forms are obligate symbionts and the sexual state is unknown (Trappe and Schenck, 1982).

Chapters in Methods and Principles of Mycorrhizal Research (Schenck, 1982) can be consulted for further information on procedures for extraction and handling of ectomycorrhizal and VAM fungi. In addition, an important resource available to researchers is the International Culture Collection