Biocontrol of soilborne plant pathogens with fungi

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Abstract

Determining mechanisms by which antagonistic fungi control plant pathogens is an important step in developing biorational approaches to disease management. These approaches should increase the probability of successful, consistent biocontrol in the field. Mechanisms of biocontrol include competition, parasitism, and antibiosis, all of which function in the rhizosphere. Competition may be the mechanism most prevalent in natural systems, but it is often difficult to observe experimentally. Parasitism can be an efficient control mechanism and has the potential to be very target specific, as in control of Sclerotinia species by Sporidesmium. Although antibiosis has not been definitively demonstrated to be the sole control mechanism of any biocontrol fungus, there is evidence for involvement of antibiotics, antibiotic-like compounds, or enzymes in control mediated by numerous fungi including isolates of Trichoderma, Gliocladium, and Talaromyces. In general, these mechanisms are not mutually exclusive; different mechanisms may act in combination to produce biocontrol. Knowledge of mechanisms can be used to design screening procedures for potential antagonists, evaluate management practices which favor antagonists, select genetically improved antagonists, and assist in registration of antagonists.

Introduction

Understanding the mechanisms through which the biocontrol of plant diseases is achieved is critical to the improvement and wider use of biocontrol methods. These mechanisms generally are classified as competition, parasitism/predation, and antibiosis (Baker, 1968; Cook and Baker, 1983). Other mechanisms, such as cross protection, do not readily fit into these categories. This classification should provide a framework to aid our understanding of biocontrol, but should not circumscribe our thinking. For example, several antagonists are known to have multiple modes of action which act against the same or different pathogens. Furthermore, different mechanisms may operate under different environmental conditions. Identification of one mode of action does not always ‘tell the whole story’.

Competition

Competition may be the mechanism most prevalent in natural systems. For example, an organism introduced into sterile soil will proliferate and establish itself to a greater extent than if it is introduced into a natural soil. It is difficult to introduce successfully an organism into soil of an undisturbed ecosystem (Garrett, 1956). This difference in performance of the organism is due to the more intense competition in the more complex ecosystem. Competition among microorganisms in soil and the rhizosphere is primarily for nutrients. Arguments concerning the importance of competition for space and oxygen continue. Organisms presumably do not compete for water in the rhizosphere or soil since the availability of water is determined by the energy status of water (water potential), which microorganisms do not affect significantly (Clark, 1965). Because nu-
trients are nearly always associated with substrates (e.g. roots, seeds, organic debris, etc.) competition for food may manifest itself as a competition for space, such as in the physical exclusion of a pathogen from a host rhizosphere due to previous colonization by an antagonist. Competition is often difficult to document since particular competitors or the objects of competition usually have not been identified and there may be several competitors involved.

One of the most familiar examples of competition as a mechanism of biocontrol is the use of the fungus Phanerochaete gigantea (Fr.:Fr.) Rattan et al. (=Peniophora gigantea Fr.:Karst.) to control root rot of pine caused by Heterobasidion annosum (Fr.:Fr.) Bref. [=Fomes annosus (Fr.:Fr.) Cooke] (Rishbeth, 1975). Heterobasidion infects healthy pine roots through root grafts from colonized tree stumps. Conidia of the antagonist P. gigantea are applied, usually in chain saw oil, to freshly cut stumps. Although the primary mechanism is competition for space by physical exclusion of the pathogen, P. gigantea also produces an antibiotic-like substance against H. annosum (Ikediugwu et al., 1970). This substance may be involved in the observed hyphal interference.

Competition between an antagonist and pathogen may be regulated by edaphic factors. For example, the chloride ion concentration of California soils is important in competition between the pathogen Pythium ultimum Trow and P. oligandrum Drechsler for organic substrates (Martin and Hancock, 1986). Soils suppressive to P. ultimum had higher levels of Cl\(^-\) than conducive soils. Pythium oligandrum had a higher degree of saprophytic activity (measured as colonization of dried cotton leaves) than P. ultimum in these soils because P. oligandrum was significantly more tolerant of Cl\(^-\) than P. ultimum. Pythium oligandrum also has been reported to be a mycoparasite of P. ultimum in dual cultures. However, both species were rarely recovered from the same leaf debris in natural systems. The ability of P. oligandrum to act as a primary colonizer of leaf tissue prevented P. ultimum from occupying that tissue and reproducing, leading to an increase in inoculum.

In another system involving two Pythium species, both competitive ability and mycoparasitism may be involved. Pythium nunn Lifshitz, Stanghellini and Baker is a more aggressive antagonist in soil than P. oligandrum since P. nunn can displace P. ultimum from organic debris (Paulitz and Baker, 1988). After 12 hours P. ultimum and P. nunn colonized 54% and 78%, respectively, of bean leaf fragments added to naturally infested soil. By 72 hours, more than 90% of the bean tissue was colonized by P. nunn alone. This reduction in colonization of tissue by P. ultimum could result in a reduction of the inoculum density of the pathogen.

Fusarium oxysporum Schlecht is sensitive to competition from antagonists. Germination of chlamydospores of F. oxysporum f. sp. melonis and f. sp. vas infectum was significantly reduced in the rhizospheres of melon and cotton, respectively, by Trichoderma harzianum Rifai (Sivan and Chet, 1989). However, this inhibition was negated by the addition of seed exudates, which suggested that competition for nutrients occurred. Several different formae speciales of F. oxysporum, causing wilts of vegetables and ornamentals, were inhibited in suppressive soils by indigenous populations of nonpathogenic F. oxysporum and F. solani (Alabouvette et al., 1979). Besides interactions between two species, interactions between a pathogen and other members of the native soil microflora can result in biocontrol. Fungi which naturally re colonized fumigated soil inhibited reproduction of F. oxysporum f. sp. radicis-lycopersici and decreased disease incidence on tomato (Marois and Mitchell, 1981).

In addition to the ability to compete with pathogens, antagonists must be able to compete with the indigenous microflora in the rhizosphere and soil. Because of the inherent ‘biological buffering’ of the natural soil system, any antagonist introduced into the system must possess certain competitive attributes. In one of the few studies designed to measure specific competitive attributes, three components of growth through soil were measured for Gliocladium roseum Bain., Thelavia terricola (Gilman and Abbot) Emmons, and Trichoderma spp. (Stack et al., 1987). The three components were percentage of carrier particles supporting hyphal growth, the