SYSTEMIC RESISTANCE INDUCED IN PLANTS AGAINST DISEASES BY COMPOSTS.

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1. ABSTRACT

Composts offer the potential to reduce the severity of plant diseases. Those caused by soilborne plant pathogens such as Pythium and Phytophthora spp. are controlled most readily. Diseases caused by Rhizoctonia and other pathogens that produce sclerotia are more difficult to control. A low percentage of compost-amended potting mixes induce systemic resistance (SR) against plant diseases. Examples include Pythium root rot and anthracnose of cucumber and bacterial leaf spots caused by Pseudomonas and Xanthomonas spp

Both the severity of symptoms of the diseases and the populations of the pathogens are reduced by SR. Biocontrol agents recovered from SR-active composts in decreasing order of efficacy include Trichoderma hamatum 382, endophytic Bacillus spp., Pantoea agglomerans E278a and strains of several fluorescent Pseudomonas spp. SR-active composts activate PR proteins in plants. However, most of the elicitation does not occur until after the plant becomes invaded by a pathogen. Thus, SR-active composts prime plants to better defend themselves against disease. The significance of this subtle defense mechanism in plants and how it relates to soil organic matter quality will be discussed.

2. INTRODUCTION

Control of plant diseases provided by composts largely is due to the activities of beneficial microorganisms supported by organic components in composts. These biocontrol agents, like pathogens and weed seeds, typically do not survive the high temperature phase of the composting process (Bollen, 1993; Hoitink and Boehm, 1999). A great diversity of microorganisms contributes to biological control. Many colonize composts immediately after peak heating during curing of composts as temperatures decline below 40 C. This process continues after utilization in the compost-amended substrate until broad spectrum disease suppression finally is achieved.

This beneficial effect provided by composts is substrate decomposition level dependent. For example, fresh organic materials that have not yet been fully colonized by microorganisms to induce microbiostasis, do not support biocontrol (Hoitink and Boehm, 1999). Fresh organic matter such as cellulose releases high concentrations of free nutrients (glucose) into the environment. This represses enzymes produced by Trichoderma required for parasitism and eradication of sclerotia of plant pathogens such as Rhizoctonia solani. Thus, both pathogens and biocontrol agents colonize fresh materials and disease develops. Pythium spp. and R. solani are examples of opportunistic plant pathogens that can destroy crops planted in fresh materials.

Utilizing CPMAS ^{13}C-NMR spectroscopy, Boehm et al, 1997 established that the concentration of "carbohydrates" in Sphagnum peat present as "protected cellulose", determines the longevity of the suppressive effect of peat substrates against Pythium root rot. More recently, Stone et al, 2001 utilizing DRIFT spectroscopy, revealed that the concentration of lignin and of lignin-protected cellulose in sawdust-bedded composted cow manure determines the longevity of this suppressive effect. Both procedures (DRIFT and NMR) are costly and not practical for field level testing of this potential for biocontrol.

Several indirect approaches have been developed to assess the potential for sustenance of biocontrol activity in soil. Some reports reveal that the quantity of microbial biomass and the rate of hydrolysis of fluorescein diacetate (FDA) in soil best predict this effect (Boehm et al, 1997; Bruns, 1996; Chen et al, 1988b; Mandelbaum and Hadar, 1990; You and Sivasithamparam, 1995). Unfortunately, fluorescein is absorbed in some soils and, therefore, this procedure is not always effective (Inbar et al, 1991). Thus, the search for a practical test continues. Several other agronomic aspects of compost quality that also affect suppressiveness of amended substrates were reviewed recently (Hoitink et al, 1997).

2.1 Development of disease suppressive microbial communities in composts

Copiotrophic bacterial taxa such as Bacillus, Pseudomonas and Pantoea spp. that are capable of functioning as biocontrol agents, rapidly colonize composts after peak heating (Kwok et al, 1987; Mandelbaum and Hadar, 1990). Oligotrophic bacteria also rapidly colonize composts after peak heating (Chen et al, 1988b) but they do not appear to contribute directly to biological control (Sugimoto et al, 1990). Actinomycetes also are major players in biological control (Hardy and Sivasithamparam, 1991; You and Sivasithamparam, 1995). Pseudomonas and Pantoea spp. are the most abundant bacterial biocontrol agents in compost-amended substrates (Alverez et al, 1995; Boehm et al, 1993).

The composition of fungal taxa active in biological control is affected by the chemical composition of the substrate from which the compost is prepared. In composts prepared from lignocellulosic wastes such as tree barks, Trichoderma spp. are the most abundant taxa (Kuter et al, 1983). They also are most effective in eradicating sclerotia of Rhizoctonia solani in such composts (Nelson et al, 1983). In contrast, Penicillium spp. are most abundant in composts prepared from grape pomace, a low in cellulose and high in sugar content material. Not surprisingly, a Penicillium was identified as an effective parasite of sclerotia of Sclerotium rolfsii in substrates amended with composted grape pomace (Gorodecki and Hadar, 1990; Hadar and Gorodecki, 1991).

Broad spectrum biological control seems to be due to interactions among several different groups of biocontrol agents (Hardy and Sivasithamparam, 1995; Kwok et al, 1987). Typically, compost-amended substrates do not become suppressive to diseases caused by several different types of plant pathogens until months after their utilization when a great diversity of microorganisms has colonized the substrate. This occurs whether composts are used in potting mixes or in soils (Kuter et al, 1988; Lumsden et al, 1983; Serra-Wittling et al, 1996; Tuitert et al, 1998). Controlled inoculation of compost during peak heating with heat-tolerant Bacillus spp. (Phae et al, 1990) or with heat-sensitive biocontrol agents after peak heating (Kwok et al, 1996; Kwok et al, 1987) can overcome this problem. This work is still in its infancy, however.

2.2 General Suppression Induced by Composts

Plant pathogens such as Pythium and Phytophthora spp. produce small propagules that can be suppressed through microbiostasis, which implies nutrient competition and antibiosis (Liebman, 1992; Lockwood, 1988). A great diversity of biocontrol agents, including Pseudomonas and Pantoea spp. contribute to this effect induced by composts (Craft and Nelson, 1996; Ellis et al, 1986; Hardy and Sivasithamparam, 1991; Hoitink et al, 1977; Lumsden et al, 1983; Mandelbaum and Hadar, 1990; Ownley and Benson, 1991; Phae et al, 1990; Sch¸ler et al, 1989; Sch¸ler et al, 1993; Widmer et al, 1998; Workneh and van Bruggen, 1994). Up to 25% of the bacterial strains recovered from cucumber root tips in compost-amended substrates can provide control of Pythium damping-off. The percent active strains in highly decomposed sources of organic matter such as H4 on the Von Post decomposition scale (Puustjarvi and Robertson, 1975) Sphagnum peat is very low (<1%; Chen et al, 1988; Chen et al, 1988b). These highly decomposed sources of organic matter are conducive to disease.

As organic matter decomposes in the suppressive less decomposed substrate, microbial biomass declines and a shift in bacterial taxa occurs, from a community that provides control to another that cannot (Boehm et al, 1997). Copiotrophs predominate in the suppressive habitat whereas pleomorphic taxa and oligotrophs predominate in the conducive system (Boehm et al, 1993; Boehm et al, 1997). The latter community resembles the community in a highly mineralized soil sensitive to erosion (Kanazawa and Filip, 1986). The decomposition level of the organic matter in soil determines the quantity of microbial biomass (Bruns, 1996; Chen et al, 1988; Chen et al, 1988b) and as mentioned above, its composition and activity. Both organic matter quality and quantity regulate this general suppression phenomenon induced by composts (Boehm et al, 1997; Stone et al, 2001).

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2.3 Specific Suppression Based on Parasitism

When all factors are optimized for controlled natural colonization of composts after peak heating by biocontrol agents, microbiostasis is established and suppression to diseases such as Pythium and Phytophthora root rots is induced (Chen et al, 1988b; Chen and Inbar, 1993; Hardy and Sivasithamparam, 1991; Hardy and Sivasithamparam, 1995; Mandelbaum and Hadar, 1990; Sch¸ler et al, 1989). Even though Pythium and Phytophthora root rots are controlled consistently, only 20% of such recolonized composts suppress sclerotia of R. solani (Krause et al, 2000). Therefore, this and other such pathogens can cause severe losses on crops planted immediately after incorporation of composts even though the other diseases are suppressed. Specific microorganisms contributing to control of plant pathogens such as R. solani can be isolated by baiting with sclerotia from naturally suppressive composts (Gorodeki and Hadar, 1990; Hadar and Gorodeki, 1991; Nelson et al, 1983). Candidate fungal and bacterial biocontrol agents recovered on selective media have been screened in bioassays to identify synergistic biocontrol interactions (Kwok et al, 1987). Through this process, highly effective compost inoculants have been developed3.

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