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Soil Biology & Biochemistry 40 (2008) 1341–1351

Soil Biology & Biochemistry

www.elsevier.com/locate/soilbio

Relative effects of biological amendments and crop rotations on soil microbial communities and soilborne diseases of potato ☆

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Received 31 October 2006; received in revised form 28 February 2007; accepted 9 March 2007
Available online 10 April 2007

Abstract

Various biological amendments, including commercial biocontrol agents, microbial inoculants, mycorrhizae, and an aerobic compost tea (ACT), were evaluated, alone and in conjunction with different crop rotations, for their efficacy in introducing beneficial microorganisms, affecting soil microbial community characteristics (SMCC), and reducing soilborne diseases of potato in greenhouse and field trials in Maine. Most amendments successfully delivered microorganisms into the soil, altering microbial populations and activity in accordance with the particular organisms added, and significantly altering SMCC (as determined by FAME analysis) to various degrees from 2 to 24 weeks. Amendment effects were greatest early on (2 weeks after amendment), but effects associated with crop treatment became more dominant at subsequent assessments (10 and 24 weeks after amendment). In field trials, effects on microbial characteristics, soilborne diseases and tuber yield were variable, with some microbial inoculants and a biostimulant producing no significant effects, whereas arbuscular mycorrhizae, reduced stem canker and black scurf by 17–28%. When used in three different 2 yr crop rotations (barley/ryegrass, barley/clover, and potato, all followed by potato), biological amendments reduced soilborne disease and improved yield in some rotations, but not others. Soil-applied ACT and the combination of ACT with a mixture of beneficial microorganisms (Mix) reduced stem canker, black scurf, and common scab on tubers by 18–33% and increased yield 20–23% in the barley/ryegrass rotation, but not in the other rotations. Mix also reduced disease (20–32%) in the barley/clover rotation only. None of the amendments significantly reduced disease in continuous potato plots. Both crop rotation and amendment treatments significantly affected SMCC, but rotation effects were more dominant. These results indicate that certain rotations were better able to support the added beneficial organisms from amendments and enable more effective biological control, and also that favorable crop rotations may be more effective than amendments in manipulating or altering SMCC. Establishment and persistence of amendment effects may depend on many factors, but an effective and supportive crop rotation is apparently important.
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Keywords: Biological amendments; Crop rotation; Soil microbial communities; Potato; Soilborne disease; Compost tea; FAME

1. Introduction

Numerous soilborne diseases are persistent, recurrent problems in commercial production of potato (*Solanum tuberosum* L.), reducing plant vigor, tuber yield, and tuber quality (Stevenson et al., 2001). Among the most prevalent in the northeast US are stem canker and black scurf, caused by *Rhizoctonia solani* Kühn, and common scab, caused by *Streptomyces scabiei* (Thaxter) Lambert and Loria. For these and other soilborne diseases, current control methods are not always practical or effective and integrated sustainable disease-control options are needed.

Active management of soil microbial communities is a promising approach as a means to develop natural suppression of soilborne diseases and improve crop productivity (Garbeva et al., 2004; Mazzola, 2004; Welbaum et al., 2004). The goal of this approach is to manipulate, alter, or augment the microbial characteristics of the soil through various management practices that increase soil microbial activity, diversity, populations of

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0038-0717/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.soilbio.2007.03.005

plant-beneficial organisms, and antagonism towards pathogens, resulting in disease suppression. Unfortunately, relatively little is known regarding the specific populations, characteristics, interactions, and relationships among plants and soil microorganisms that confer stable disease suppressiveness. Although the mechanisms of microbial disease suppression and organisms responsible are known for some specific pathogen and disease-suppressive soils, such as take-all decline (Raaijmakers and Weller, 1998; Weller et al., 2002), in most cases, and particularly for nonspecific general suppression of multiple diseases, the microbial components necessary and the means to achieve adequate disease suppression in a particular field with a history of disease problems are just not known.

It is known that plants and plant products (organic amendments, crop residues, green manures) can dramatically affect soil microbial communities, and are primary drivers of soil microbial dynamics (Garbeva et al., 2004; O'Donnell et al., 2001; van Elsas et al., 2002), and thus may be important components in establishing and maintaining soil suppressiveness. Crop rotations and residue amendments have been shown to have major effects on soil microbial communities and can result in significant reductions in soilborne diseases (Abawi and Widmer, 2000; Bailey and Lazarovits, 2003; Davis et al., 1996). Previously, our research with crop rotations, cover crops, and green manures established that different crop rotations resulted in distinct differences in soil microbial community characteristics (SMCC) (Larkin, 2003) that were associated with suppression of soilborne potato diseases (Larkin and Honeycutt, 2006; Larkin et al., 2006a), and that *Brassica* rotations and green manures could reduce multiple soilborne diseases of potato (Larkin and Griffin, 2007).

However, addition of microorganisms, either to provide specific known beneficial or pathogen-antagonistic strains, or to supplement the indigenous microbial biodiversity, may enhance the development of microbial disease suppression (Cook, 1993). Biological amendments of various types, including recognized biological control agents with known activity against specific pathogens, and diversified microbial inoculants may effectively introduce, augment, or stimulate soil populations of plant-beneficial microorganisms, and may also interact to some degree with crop rotations. Previous research indicated that several established biocontrol agents, including *Bacillus subtilis*, *Trichoderma harzianum*, and *Trichoderma virens* can reduce soilborne potato diseases in the greenhouse and field (Brewer and Larkin, 2005; Larkin, 2004).

There has also been much interest and activity regarding various alternative and diversified biological amendments with potential to enhance, restore, or regenerate soil microbial communities and soil health. Among these, compost teas, produced by mixing compost with water and other ingredients in various ways and incubating (or "brewing") for defined periods to extract or enhance the microorganisms, have had some success in suppressing disease and increasing crop growth (Scheuerell and Mahaffee, 2002, 2004, 2006). In Asia, the use of a defined mixture of fermenting yeast, lactic acid bacteria, phototrophic bacteria, and other microorganisms, called effective microorganisms or EM, has been associated with improving productivity and disease control (Higa, 1991, 1994). Arbuscular mycorrhizae are well known to benefit plant growth, but supplemental additions may also help suppress disease (Jeffries et al., 2003; Harrier and Watson, 2004). In addition, amendments known as biostimulants (organic acids, enzymes, plant extracts, vitamins, growth regulators, etc.) are formulated to stimulate microbial activity in soil and on plant roots, theoretically resulting in improved crop growth and disease suppression.

All of these amendments provide different types and assemblages of microorganisms, and potentially may have different effects on and interactions with existing soil microbial communities, and presumably different potential benefits and limitations. The role and extent of effects of such biological amendments on soil microbial communities, and vice versa, and as affected by crop rotations and related factors, remains a critical area of investigation and increased understanding before development of biological control and natural disease suppression can be implemented to its fullest (Handelsman and Stabb, 1996; Milner et al., 1997). The objectives of this research were to evaluate a variety of different biological amendments in conjunction with different crop rotations for their effects on SMCC, soilborne diseases, and tuber yield in greenhouse and field trials.

2. Materials and methods

2.1. Biological amendments

Amendments representative of a variety of different types of biological amendments were evaluated, including three commercially available biological control agents with known activity against *R. solani* and other soilborne pathogens, four different microbial inoculants containing distinctly different classes and types of microorganisms, and a biostimulant. The biological control agents used (followed by abbreviations to be used in parantheses) were: *Bacillus subtilis* GB03 (*Bsub*) (Kodiak; Bayer CropScience LP, Research Triangle Park, NC), *Trichoderma virens* Gl-21 (*Tvir*) (SoilGard 12G; CertisUSA, Inc., Columbia, MD), and *Trichoderma harzianum* strain T-22 (*Tharz*) (RootShield; BioWorks, Inc., Geneva, NY). Bacterial and fungal cell counts in the commercial formulations were determined using standard serial dilution plating on 0.1% tryptic soy agar (TSA) for bacteria and potato dextrose agar (PDA) with 50 mg chlortetracycline and 1 ml/L tergitol for fungi (Larkin, 2003). Bacterial counts of $\sim 1\times10^9$ CFU/g formulation for *Bsub* and fungal counts of $6.5–7\times10^6$ CFU/g for *Tvir* and *Tharz* were observed.

EM (EM-1; EMRO USA, Tucson, AZ, USA), a mixture of fermenting yeast, lactic acid bacteria, phototrophic bacteria, and other microorganisms, was obtained as a