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Control of soilborne potato diseases using *Brassica* green manures ☆

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Abstract

Brassica crops used in crop rotations and as green manures have been associated with reductions in soilborne pests and pathogens. These reductions have been attributed to the production of volatile sulfur compounds through a process known as biofumigation, and to changes in soil microbial community structure. In this study, selected *Brassica* crops, including canola, rapeseed, radish, turnip, yellow mustard, and Indian mustard, were evaluated for control of various soilborne potato pathogens and diseases in culture, in greenhouse trials, and in field trials on commercial potato farms. In in vitro assays, volatiles released from chopped leaf material of *Brassica* crops and barley inhibited growth of a variety of soilborne pathogens of potato, including *Rhizoctonia solani*, *Phytophthora erythroseptica*, *Pythium ultimum*, *Sclerotinia sclerotiorum*, and *Fusarium sambucinam*, with Indian mustard resulting in nearly complete inhibition (80–100%). All *Brassica* crops and barley reduced inoculum levels of *R. solani* (20–56% reduction) in greenhouse tests, and radish, rapeseed, and Indian mustard reduced subsequent potato seedling disease by 40–83%. In an on-farm field trial at a site with a substantial powdery scab problem, Indian mustard, rapeseed, canola, and ryegrass grown as green manure rotation crops reduced powdery scab in the subsequent potato crop by 15–40%, and canola and rapeseed reduced black scurf by 70–80% relative to a standard oats rotation. At another field site where common scab was the primary disease problem, an Indian mustard green manure reduced common scab by 25%, and rapeseed, yellow mustard, and ‘Lemtal’ ryegrass also reduced black scurf relative to a standard ryegrass rotation. Disease reductions were not always associated with higher glucosinolate-producing crops, and were also observed with non-*Brassica* crops (barley and ryegrass), indicating other mechanisms and interactions are important, particularly for control of *R. solani*. Overall, Indian mustard was most effective for reducing powdery scab and common scab diseases, whereas rapeseed and canola were most effective in reducing *Rhizoctonia* diseases. These results indicate that *Brassica* crops have potential for use as green manures for the control of multiple soilborne disease problems.
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1. Introduction

Numerous soilborne diseases are persistent, recurrent problems in potato production, resulting in reduced plant growth and vigor, lower tuber quality, and reduced marketable yield. Common soilborne diseases in the Northeastern US and other potato-growing regions include: stem canker and black scurf caused by *Rhizoctonia solani* Kühn; common scab, caused by *Streptomyces scabiei* (Thaxter) Lambert & Loria; powdery scab, caused by *Spongospora subterranean* (Wallr.) Lagerh. f. sp. *subterranea* Tomlinson; white mold, caused by *Sclerotinia sclerotiorum* (Lib.) de Bary; pink rot, caused by *Phytophthora erythroseptica* Pethybr.; Pythium leak, caused by *Pythium* spp.; silver scurf, caused by *Helminthosporium solani* Dur. & Mont.; Verticillium wilt, caused by *Verticillium dahliae* Kleb.; and Fusarium dry rot, caused by *Fusarium sambucinum* (Fr.) Sacc. For some of these disease problems, chemical fumigants and seed treatments can provide some control, but they are not always practical or effective, and integrated, sustainable disease control options are desirable. For other diseases, such as powdery

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scab, effective control options have not yet been developed (Harrison et al., 1997).

The importance of powdery scab as a disease problem has been increasing in recent years, in Maine as well as in other potato-growing regions (Harrison et al., 1997). This disease causes lesions on the surface of tubers, seriously affecting tuber quality and marketability, and is especially problematic for seed producers. In addition, the confirmation of potato mop-top virus (PMTV), which is vectored solely by the powdery scab pathogen, in Maine and potato-growing regions throughout the US and Canada (Lambert et al., 2003; Xu et al., 2004), has made control of powdery scab an even greater priority. This disease represents a recurring problem because once an area is infested with the pathogen, it will persist indefinitely. The pathogen produces long-term resting spores that can survive many years in soil. Most importantly, there are currently no effective control measures available (Harrison et al., 1997; Stevenson et al., 2001).

One approach with potential to control multiple soilborne pathogens and diseases is the use of effective crop rotations selected for their ability to reduce soilborne potato diseases. In particular, the use of *Brassica* spp. and related plants as cover, rotation, or green manure crops for reducing soilborne pathogens and diseases has been receiving increased attention in recent years. *Brassica* crops, which include broccoli, cabbage, cauliflower, kale, turnip, radish, canola, rapeseed, and various mustards, produce sulfur compounds called glucosinolates that break down to produce isothiocyanates that are toxic to many soil organisms as part of a process referred to as biofumigation (Sarwar et al., 1998), and have been successfully used to reduce soilborne populations of fungal pathogens (Brown and Morra, 1997; Kirkegaard et al., 1996; Muelchen et al., 1990; Olivier et al., 1999; Smolinska and Horbowicz, 1999), nematodes (Buskov et al., 2002; Mojtahedi et al., 1993), and weeds (Boydston and Hang, 1995; Brown and Morra, 1995), and to improve soil characteristics and crop yield (McGuire, 2003). Other studies have also indicated that mechanisms other than isothiocyanate production may be important in the reduction of soilborne diseases by *Brassica* crops (Mazzola et al., 2001). Cohen et al. (2005) for example, demonstrated that suppression of *R. solani* by *Brassica napus* seedmeal was associated with specific changes in soil microbial communities and was unrelated to levels of glucosinolate. Other researchers have also noted the role of the stimulation of soil microbial activity or the alteration of soil microbial communities in suppression of specific diseases (Larkin and Honeycutt, 2006; Smolinska, 2000).

Nonetheless, volatile compounds and specific isothiocyanate products released from *Brassica* plant material have been shown to inhibit a variety of soilborne pathogens, including *Gaumanomyces graminis*, cause of take-all of wheat (Angus et al., 1994), *Aphanomyces euteiches*, cause of aphanomyces root rot of peas (Lewis and Papavizas, 1971), and *Fusarium oxysporum* (Smolinska et al., 2003), as well as various post-harvest pathogens (Mari et al., 1993). Inhibition of potential potato pathogens, including *Pythium ultimum, R. solani, F. sambucinam*, and *V. dahliae* (Charron and Sams, 1999, Mayton et al., 1996), has also been demonstrated with compounds released from certain *Brassica* cultivars. However, glucosinolate concentrations and the resulting production of different forms of isothiocyanates vary greatly among different *Brassica* species and even among cultivars within species (Kirkegaard and Sarwar, 1998), and are also affected by environmental conditions and plant development (Kirkegaard et al., 1996; Sarwar and Kirkeagard, 1998).

In our field research with different potato cropping systems conducted over the last several years, we have consistently observed that canola and rapeseed crops prior to potato result in substantially lower soilborne disease due to *Rhizoctonia* and common scab than many other rotations (Larkin and Honeycutt, 2002, 2006). Disease reductions have ranged from 25% to 75% over several seasons relative to no rotation or less successful rotations. The current research was established to determine if these *Brassica* crops had potential control activity against a wider variety of soilborne potato diseases, and whether specific *Brassica* crops can provide better disease control of specific pathogens than others. The objectives of these studies were to evaluate selected *Brassica* crops for their ability to inhibit soilborne potato pathogens in vitro, reduce soilborne pathogens and disease development in greenhouse trials, and to reduce soilborne potato diseases in on-farm field trials.

2. Materials and methods

2.1. In vitro pathogen inhibition assays

Local isolates of selected soilborne fungal pathogens, including *R. solani*, *Phytophthora erythroseptica*, *Pythium ultimum*, *Sclerotinia sclerotiorum*, *F. sambucinum*, *V. dahliae*, *Helminthosporium solani*, and *Fusarium oxysporum* (cause of Fusarium wilt), which were previously isolated from diseased potato plants or tubers in Maine, were cultured on potato dextrose agar (PDA) and grown at 25 °C for 7–14 d prior to use in in vitro inhibition assays. Two additional non-pathogen fungal isolates collected from soil, *Trichoderma virens* and *Penicillium chrysogenum*, were used to represent the common soil microorganism groups *Trichoderma* spp. and *Penicillium* spp. for comparison with potato pathogens in in vitro tests. *Brassica* crops representing a range of crop types and potential glucosinolate levels were selected, including canola, rapeseed, radish, turnip, yellow mustard, and Indian mustard as identified in Table 1. The non-Brassica crop plants, barley and ryegrass, and a non-treated control (no plant material) were used for comparison. Seeds were planted in a potting mix (Metro-Mix 200, Scotts Horticultural Products, Marysville, OH) to develop a lawn of growth in several

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