SUPPRESSION OF RHIZOCTONIA ROOT ROT BY *STREPTOMYCES* IN *BRASSICA* SEED MEAL-AMENDED SOIL

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The use of plant-based organic residue as soil amendments offers a realistic alternative to broad spectrum biocides for the management of soil-borne plant pathogens. Much research in the application of organic amendments has employed a pragmatic "try it and see what happens" approach. Enticing results from one study often could not be extended to other locations due to the inherent complexity of field studies, insufficient understanding of soil microbial ecology, and lack of knowledge regarding the molecular workings of plant disease resistance. However, read from a modern perspective, the results of some of these investigations present clues that may lead to at least some resolution of the problem.

Bioactive plant products, introduced either as a cover crop or soil amendment, have acquired significant use as a disease control treatment, particularly within the organic farming community. Members of the plant family Brassicaceae, including *Brassica napus*, produce glucosinolates which upon hydrolysis yield biologically active compounds including isothiocyanates. As isothiocyanates have a broad spectrum of activity, investigators have focused on the use of these plants as a "biofumigant", where incorporation of residues into soil ultimately results in release of active products. However, evidence suggests that certain of these plant residues may operate in the suppression of fungal pathogens via a different, as yet unidentified, mechanism. For example, reports exist of the effective use of *B. napus* residues to control soilborne disease even though separate reports suggest that these plant residues yield isothiocyanates having low antimicrobial activity (1). We have demonstrated that the suppression of certain apple root pathogens and parasites, including *Rhizoctonia solani* and *Pratylenchus penetrans*, is obtained via the incorporation of *B. napus* seed meal (RSM) irrespective of the glucosinolate content of the amendment (2). When used in conjunction with a mefenoxam post-plant soil drench, at certain replant sites RSM treatments provided apple growth and yields equivalent to pre-plant soil fumigation (3).

Seed meal is a superior alternative to a Brassica green manure crop from several perspectives including the ability to effectively control rates of residue application, the ease at which residue amendment can be incorporated into production practices, the lack of lost production periods and associated costs of producing the green manure crop, and a reduction in fertilizer costs due to the high nitrogen content of the seed meal. However, effective and predictable use of these materials as a pest management option requires unbiased knowledge as to the mechanism and spectrum of disease control which can be achieved. Studies were conducted to assess the impact of RSM treatments on soil microbial communities with the goal of clarifying a possible role for resident soil microorganisms in the observed suppression of *R. solani*.

Incorporation of RSM into orchard soil at 3 weeks prior to planting significantly lowered the frequency of Gala seedling root infection by *R. solani* regardless of whether the meal had been steam pasteurized previously. Disease control did not result from a biofumigation response as growth of *R. solani* through the soil profile was not impeded by RSM amendment (4). In contrast, steam pasteurization of the soil after incorporation of the amendment, which eliminated most bacteria except for *Bacillus* spp., abolished the RSM protective effect. Nitric oxide (NO), a known inducer of plant systemic defense, is released by nitrifying bacteria in RSM-amended soil (Fig. 1). When the nitrification inhibitor nitrapyrin was applied to soil at 10 mg kg^{-1}, release of NO and control of *R. solani* was abolished when seedlings were planted soon after RSM incorporation. However, disease control in these soils was unaffected when seedling planting was delayed until 4 weeks after RSM incorporation. Thus, organisms other than nitrifying bacteria are probably responsible for longer term RSM-induced disease suppression.

The proliferation of resident *Streptomyces* spp. is consistently observed in response to RSM amendment. In part, this may result from the activities of by the most abundant protozoan in RSM treated soils, *Naegleria americana*, which exhibit a significant preference for feeding on bacteria other than *Streptomyces.* The vast majority of *Streptomyces* recovered from the apple rhizosphere produce NO via the activity of nitric oxide synthase (4). The presence of nitrapyin had no impact on the RSM-induced proliferation of *Streptomyces* spp., and does not influence yield of NO via nitric oxide synthase.

Split-root assays demonstrated that amendment of soil with 0.5% RSM confers systemic protection against *R. solani* AG-5 root infection of apple seedlings (Table 1). The induction of a plant defense response appears to be indirect, and is likely mediated through the resident apple rhizosphere microflora when cultivated in RSM-amended soils. This premise is supported by the fact, cited above, that pasteurization of RSM treated orchard soil eliminates the capacity of this amendment to provide control of Rhizoctonia root rot. Suppressiveness could be restored to pasteurized RSM-amended soil by adding any of several *Streptomyces* strains (Table 1). In total, our data suggest that NO is functioning as the inducer of plant defenses in response to RSM soil amendment. Although nitrifying bacteria likely have a role in suppression of Rhizoctonia root rot observed immediately post-RSM amendment, long-term disease control functions through an alternative microbial community, which we believe includes resident *Streptomyces* spp. However an unquestionable role for NO-producing *Streptomyces* in this response awaits further study.

References:

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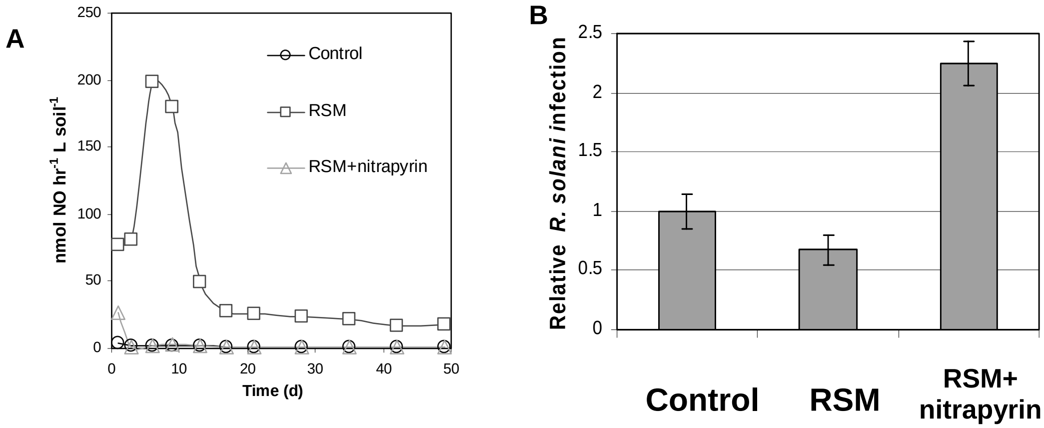

Fig 1. Impact of nitrapyrin treatment on yield of nitric oxide (A). Control of Rhizoctonia root rot of apple in RSM amended soils when seedlings were planted 24 h after application of soil treatments (B).

Table 1. *Rhizoctonia solani* infection frequency for Gala seedling roots in soils amended with *Brassica napus* seed meal or individual *Streptomyces* sp. strains

Soil Treatment	Strain	*R. solani* infection frequency (%)† Single container	Split-root container
0.5% RSM	None added	13.3[a]	22.1[a]
Stream pasteurized	None added	38.9[c]	47.1[c]
	CR2	7.2[a]	17.1[a]
	SCV22	17.2[ab]	25.7[ab]
	RR2	15.0[ab]	32.1[b]
	CVR44	25.7[a]	28.6 [ab]

†Values followed by the same letter are not significantly different (P > 0.05).