PAPER MILL SLUDGE AND COMPOST EFFECTS ON DISEASE INCIDENCES IN A VEGTABLE ROTATION

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Organic matter inputs, including plant residues, manure, and composted organic wastes, have been shown to significantly reduce the severity of a wide variety of root diseases, including those caused by Pythium spp., in natural systems (Perrin, 1986) and field systems (Lewis et al, 1992). Compost amendments have also been shown to reduce the incidence of bacterial spot in field tomato (Miller et al, 1998). Organic matter (OM)-mediated suppression of foliar diseases might be due to the induction of induced systemic resistance (ISR) by microorganisms supported by the OM. Induced resistance is a "state of enhanced defensive capacity" triggered by specific contact stimuli, whereby the plant's active defenses are activated by a subsequent challenging pathogen (van Loon et al. 1998).

Recent work carried out by Zhang and colleagues (1998, 1996) have demonstrated that cucumbers grown in compost amended potting soils are systemically resistant to foliar diseases and show an increase in b-1,3-glucanase (Zhang et al. 1998) and peroxidase activity (Zhang et al. 1996) following inoculation with a challenge pathogen. However, there are few reports on the effects of multi-year amendments on disease incidence in crops in rotation.

The purpose of this study is to investigate the effects of organic amendment type, rate, decomposition level, and annual amendment on induced systemic resistance and field disease incidence in a three year sandy soil vegetable rotation. Paper mill sludge (PS), PS composted alone (PSC), and PS composted with bark (PSB) are amended at low (L) and high (H) rates (PS, 22/44 Mg ha-1; others, 38/76 Mg ha-1) to a Plainfield loamy sand each spring. The field was planted to potato "Russet Burbank" in 1998, snap bean "True Blue" in 1999, and will be planted to pickling cucumber in 2000. All naturally-occurring field disease incidence have been assessed. Additional experiments utilizing amended and non-amended field soils in a controlled environment are also being carried out to screen for potential and will be related back to field data.

Results and Discussion

Pythium leak incidence in stored potato tubers grown in first-year amended soils was reduced (P=0.10) in PSB low rate, PSC high rate and PS high rate treatments. All second-year amended treatments reduced (P=0.05) cucumber damping-off and aerial Pythium of snap bean. In contrast, only PSC reduced the incidence of foliar and pod brown spot of snap bean (Table 1).

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Table 1. Yield and Disease Data from 1998 and 1999 Field Trials.

Treatment	Potato (1998)	Snap Bean (1999)				
	Pytium leak	Snap Bean Yield	Pythium Damping-off index[2]	Aerial Pythium Incidence	Foliar Brown Spot[3]	Pod Brown Spot Incidence[4]
PS 10 T/A	6.3b[1]	6.37ab	1.875a	3.0a	2.3b	22.9b
PS 15 T/A	5.1a	7.19ab	1.425a	1.7a	3.4b	34.3b
PSC L	10.3b	7.43c	1.550a	1.5a	1.5a	12.1a
PSC H	4.8a	6.27a	1.825a	1.7a	1.1a	7.6a
PSB L	4.1a	6.80abc	1.725a	1.9a	2.4b	25.3b
PSB H	8.7b	6.46ab	1.725a	1.7a	2.5b	23.3b
Control	13.1b	6.08a	3.075b	15.0b	3.9d	24.7b
LSD (P=0.05)	9.7	1.07	0.682	6.6	0.6	11.6

[1] Treatments are significantly different at *P*=0.10. In all other cases, treatments are significantly different at *P*=0.05.
[2] Disease indx based on 1-4 scale.
[3] Disease index based on Horsfall-Barratt scale.
[4] Proportion of diseased pods.

PS, PSC, and PSB all have potential to reduce the incidence of root, tuber, and foliar diseases caused by Pythium spp. Organic matter-mediated suppression of Pythium damping-off and root rots has been reported frequently in both container and field systems (Hoitink et al, 1991; Lewis et al, 1992; Perrin, 1986; Stone, 1997). However, reductions in incidence of Pythium leak of potato and aerial Pythium of snap bean have not been reported previously to our knowledge.

PSC appears to have the greatest potential to suppress brown spot of snap bean. There have been no previous reports of OM- or plant growth promoting rhizobacteria (PGPR)-mediated brown spot suppression to our knowledge. However, OM-mediated suppression of bacterial spot in field grown tomato has been reported previously (Miller et al, 1998). In addition, seed bacterization with a PGPR strain, *Pseudomonas fluorescens* S 97, has been shown to reduce incidence of halo blight in container grown snap bean (causal agent Pseudomonas syringae pv. phaseolicola (Alstrom, 1995). There have been no previous reports of brown spot suppression to our knowledge.

Suppression of all diseases caused by *Pythium* spp. (except Pythium leak) was supported strongly by all amendments regardless of type. Pythium leak was suppressed by PSB L, PS H, and PSC. Foliar brown spot was suppressed to some extent by all amendments, but most strongly by PSC, while suppression of brown spot incidence on bean pods was specific to PSC. These differences will be investigated further.

Significant suppression of bacterial spot of Arabidopsis was also observed with PSB H and PSC in growth chamber bioassays (*P*=0.05) at a level similar to chemical induction of induced resistance with a Benzothiadiazole (BTH), whereas HiPS and LoPSC were not significantly different from the control in two of three bioassays (Fig. 1). Similar suppression of bacterial spot in Arabidopsis via ISR has been demonstrated previously in association with PGPR strains of *Pseudomonas* (van Loon et al. 1998). In addition, compost-amended potting mixes have also been shown to suppress this disease and increase the expression of several defense-related genes (Zhang et al, 1996 and 1998). Therefore, some form of induced resistance in suppression of brown spot and other field crop diseases will be explored further.

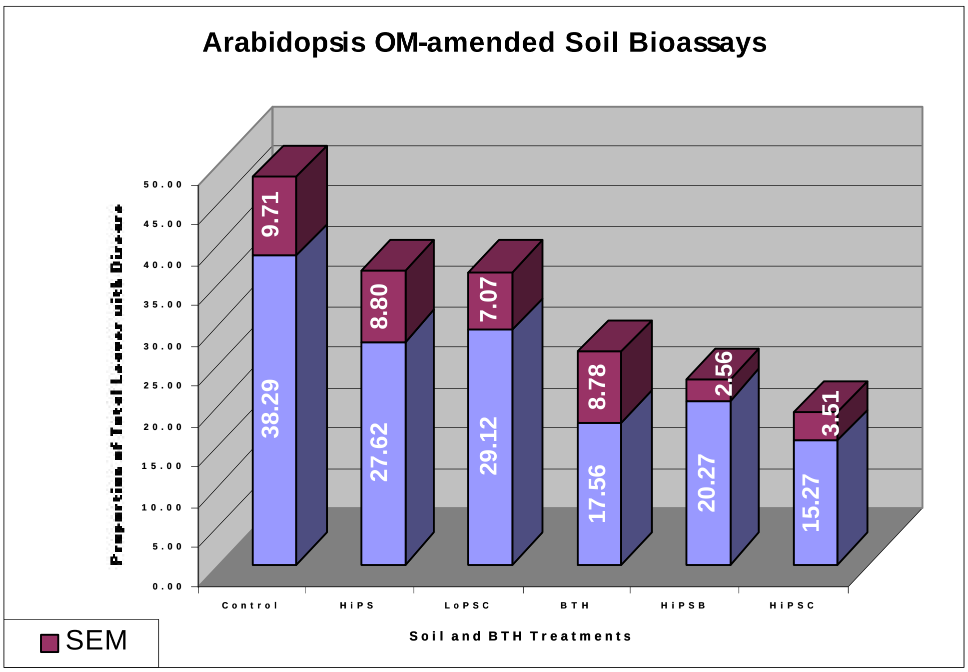

Figure 1. Arabidopsis OM-amended soil bioassay. Values are averaged across three replicate experiments with similar results. BTH (Benzothiadiazole; 300µM) was applied to plants grown in control, non-amended, field soil a week prior to challenge inoculation.

Ongoing Research

Future work will include assaying for OM-mediated differential gene expression using known defense genes as probes and differential display techniques. The goals are 1) to identify genes that are predictive of OM-mediated ISR, 2) to develop a plant reporter system, and 3) to relate ISR and disease incidence in field-grown plants.

OM composition will be assessed through the use of DR-FTIR and NMR spectroscopic techniques. The rate of hydrolysis of fluorescein diacetate will be measured as an indirect indicator of OM quality. Ultimately, OM content, composition and a wide range of other soil properties will be related to the potential for induced systemic resistance as well as overall and specific field disease incidence.

This field trial will be conducted for at least six years and two complete three-year rotation cycles (potato/snap bean/cucumber). Amendments will be applied each year and the longer-term impacts of amendment and rotation disease incidence in all crops and ISR will be assessed over time. Effects in subsequent years and crops may be very different. Comprehensive soil data and crop data will also be collected.

Materials and Methods

Field plot location is at UW Hancock Agricultural Experiment Station; Hancock, WI. The soil type is a Plainfield loamy sand. Amendments were applied two weeks prior to planting in 1998 and four weeks prior to planting in 1999.
Amendments include:

1) raw paper mill sludge (PS; applied at 50 and 100% potato N requirement; 22/44 Mg ha-1 ;10/20 dry T/A).
2) paper mill sludge composted alone (PSC; 38/76 Mg ha -1 ;17/35 dry T/A).
3) paper mill sludge composted with bark (PSB; 38/76 Mg ha -1 ;17/35 dry T/A).

The field was planted to potato "Russet Burbank" in 1998 and snap bean "True Blue" (brown spot susceptible) in 1999.

Cucumber damping-off bioassay: Four seeds of cucumber "Straight Eight" were sown in treatment soils infested at potting in 3" PVC tubes with 0.05 g soil inoculum of *Pythium ultimum* 211 per liter mix. Severity was rated 10 days after planting on a scale: 1 = symptomless; 2 = emerged but wilted, chlorotic or with visible lesions on the hypocotyl; 3 = post-emergence damping-off; 4 = pre-emergence damping-off. PVC tubes were sunk into field plots.
Pythium leak of potato (causal agent *Pythium ultimum*): Proportion of infested tubers were counted in storage potatoes (natural infestation).
Aerial Pythium of snap bean (causal agent *Pythium ultimum*): Proportion of infected plants / 40 row ft were counted (natural infestation).
Brown spot of snap bean (causal agent *Pseudomonas syringae* pv *syringae*): Foliar incidence was rated accoding to the Horsfall-Barratt rating scale of 0 (no infection) to 11 (all foliage and stems dead) and converted to midpoint percentages. Pods were rated as proportion of pods infected.
Bacterial spot of Arabidopsis (causal agent *Pseudomonas syringae* pv. *syringae* strain DC3000): Seeds of *Arabidopsis thaliana* ecotype 'Columbia' were sown in treatment soils. Plants were challenged at five weeks via dip inoculation into a 5.8 x 10^6 CFU/ml bacterial solution. Disease severity was assessed after four days as the proportion of total leaves showing disease.

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