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Compost Amendments Decrease *Verticillium dahliae* Infection on Potato

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Indigenous soil microorganisms contribute to disease suppression in cropping systems by reducing and competing with pathogen populations, thereby limiting disease severity. Various communities of indigenous microorganisms in any particular soil have adapted to the specific environmental conditions. If the soil around the plant roots could be altered to favor the indigenous soil microorganisms relative to the plant pathogen, the survival and proliferation of indigenous soil microorganisms, and thus effectiveness of biological control, may be increased. Wood chip-polyacrylamide (PAM) cores were used to alter the soil environment in a greenhouse study to favor indigenous soil microorganisms in vegetable and manure compost to reduce *Verticillium dahliae* infection of potato (*Solanum tuberosum* L.) plants. Potato plants growing in soils amended with vegetable compost-wood chip-PAM cores had significantly lower visible (V_{vis}) and isolation (V_{iso}) *V. dahliae* infection rates than control soils and soils with dairy or vegetable compost alone. Soils amended with wood chip-PAM-dairy compost cores had significantly lower V_{vis} and isolation V_{iso} than control soils and soils with dairy compost. Soils with wood chip-PAM cores and soils with wood chip-PAM-vegetable compost had greater microbial biomass / *Verticillium dahliae* biomass (MB / VB) ratios in soil than control soils or in soils amended with compost alone. MB / VB ratios in wood chip-PAM cores and wood chip- PAM-vegetable compost were greater than in wood chip-PAM-dairy compost cores. V_{yis} correlated in a quadratic relationship with the MB / VB ratio (r^2=0.76). As MB / VB ratio increased V_{yis} decreased. Although field studies with several crops and economic evaluations are necessary, this greenhouse study provides evidence that a wood chip-PAM or wood chip- PAM-vegetable compost soil amendment may be a viable method to control some soil diseases in high value crops.

Introduction

Verticillium wilt caused by *Verticillium dahliae* is a major disease problem in potato (*Solanum tuberosum* L.) production. Treatment of soil with metam-sodium and long rotations are the only two practical approaches to reduce *V. dahliae* inoculum density in the state of Idaho. New potato varieties that are resistant to *V. dahliae* have been recently developed (Davis *et al.* 1994a; 1994b; Mohan *et al.* 1992). These new varieties along with proper fertilization, crop rotations and irrigation management are also used to control the pathogen to some extent (James *et al.* 1994; Davis *et al.* 1994b). Since potato varieties respond to cultural management, research has focused on alternative cultural methods to control *V. dahliae.*

Indigenous microbes are effective contributors to disease suppression in cropping systems and mediate effects of numerous cultural practices to reduce pathogen populations and limit disease severity (Davis *et al.* 1996; Strausbaugh 1993). A powerful biological control strategy in the soil environment is competition. Indigenous soil microorganisms will compete for colonization of soil organic material including host roots with facultatively obligate plant pathogens, until plant pathogenic microorganisms cannot find adequate resources to produce a population capable of infecting the host (Baker and Scher 1987). If the soil around the plant roots could be altered to favor the indigenous soil microflora relative to the plant pathogen, the survival and proliferation of indigenous soil microorganisms, and thus effectiveness of biological control may be increased.

It has been recognized that successful control of plant disease may be affected by changing the behavior of pathogens in the rhizosphere (Bailey and Gilligan 1997). Biocontrol of root disease is largely based upon competition for rhizosphere resources between the biocontrol organism and the pathogen provided that their respective niches overlap (Cook 1993). Competitive colonization of rhizosphere by the biocontrol organism and use of resources is thought to exclude many rhizosphere pathogens (Gilligan and Bailey 1997). Cook *et al.* (1997a; 1997b) reported that

effectiveness of biocontrol of *Botrytis cinerea* increased when microorganisms were attached to the surface of the fungal pathogen or the phylloplane compared to same microbial species that remained unattached.

Polyacrylamides (PAMs) are polymers made up of many repeating subunits (monomers). When PAM molecules are dissolved in water and adhere to microorganisms or nutrients, they may stay dissolved until the molecule adheres to an object. The ability of PAM to adhere to soil and roots has been understood for some time (Barvenik 1994). Polyacrylamide Superfloc® A836 was found to adhere indigenous microorganisms to roots. (Sojka and Entry 2000). In this experiment, the PAM Superfloc® A836 copolymer was used to help adhere indigenous microorganisms in dairy waste to wood chips and potato roots. The objective of this study was to determine the efficacy of vegetable and manure compost in a wood chip PAM medium to manage soil microbial communities in order to alter the soil environment to favor indigenous microorganisms to reduce *Verticillium dahliae* infection of potato plants.

Methods and Materials

Experimental Design

The greenhouse experiment was arranged in a randomized block design with soil containing different concentrations of *V. dahliae* as blocks (Kirk 1982). Treatments were: 1) soil that did not receive wood chip-PAM treatments (control), 2) soil amended with a core containing a wood chip-PAM mixture without compost, 3) soil amended with a core containing a wood chip-PAM mixture with a dairy manure compost amendment, 4) soil amended with a core containing a wood chip-PAM mixture with a vegetable compost amendment, 5) soil that received dairy compost amendment without a wood chip-PAM treatment and 6) soil that received a vegetable compost amendment without a wood chip-PAM treatment. The experiment had 6 treatments × 3 soils with different concentrations of *V. dahliae* × 3 replications × 6 separate plants evaluated from each treatment × soil. A total of 324 samples for each parameter were taken during the experiment.

Soil

The three soil sources, all with the same classification, used in this experiment were collected from the University of Idaho Research and Extension Center at Aberdeen, Idaho. All three soil sources are characterized as a silt loam (Azad *et al.* 1985). Prior to collection, these soils had been planted to a variety of crops including barley (*Hordeum vulgare L.*), wheat (*Triticum aestivum* L.) and potato for more than 70 years; these soils had a long history of *V. dahliae* infection in the potato crop (Davis *et al.* 1996). Soil 1 averaged 158 colony forming units (cfu) of *V. dahliae* g^{-1} soil. This soil had a pH of 8.2, a bulk density of 1.08 g cm^3, water holding capacity of 20 cm^3 water m^3 soil (20%), and contained 1.3% organic matter, 14 mg NO_3 kg^{-1} soil 12 mg P kg^{-1} soil, and 148 mg K kg^{-1} soil. Soil 2 averaged 140 cfu of *V. dahliae* g^{-1} soil. This soil had a pH of 8.0, a bulk density of 1.17 g cm^3, water holding capacity of 18 cm^3 water m^3 soil (18%), and contained 0.9% organic matter, 23 mg NO_3 kg^{-1} soil, 4.7 mg P kg^{-1} soil, and 62 mg K kg^{-1} soil. Soil 3 averaged 108 cfu of *V. dahliae* g^{-1} soil. The soil had a pH of 7.8, a bulk density of 1.02 g cm^3, water holding capacity of 24 cm^3 water m^3 soil (24%), and contained 1.6% organic matter, 16 mg NO_3 kg^{-1} soil, 10 mg P kg^{-1} soil, and 120 mg K kg^{-1} soil.

Polyacrylamide Application

The polyacrylamide copolymer used was a dry granular material having an approximate molecular weight of 12-15 Mg/mole (CYTEC Industries of Wayne, New Jersey and under the trade name Superfloc® A836). This PAM formulation had a negative charge density of approximately 18%, achieved by substitution of a sodium formate group for one of every 5 amide groups, with the negative charge resulting from disassociation of sodium when the PAM was dissolved in water. This commercial PAM product also contained approximately 15% urea by weight. PAM is a nontoxic polymer (Barvenik 1994; Seybold 1994) that will degrade at approximately 10% yr^{-1} (Abdelemagid and Tabatabai 1982).

Treatments

The potatoes were grown in 3.0 L (11.3 gal) black plastic pots containing 3 kg (6.6 lb) soil. Control pots contained only soil (without PAM cores or amendments). A 7.0 cm diameter × 15 cm (2.57 diameter × 6.25 ") deep core was removed from the center of the soil in each pot receiving wood chip-PAM or wood chip- PAM-compost cores. Each hole was filled with a wood chip-PAM or wood chip-PAM compost core. All cores were comprised of a wood chip- PAM treatment which was a mixture of 48.9 g (1.7 oz) Ponderosa pine (*Pinus ponderosa* Dougl. Ex. Laws.) wood chips, 22.3g (0.78 oz) nutrient solution (Arnon and Hoagland 1940) and 0.6 g PAM liter $^{-1}$ solution. Fresh wood chips were 5 × 5 × 1 cm (2 × 2 × 0.5 ") in size. Cores having the wood chip-PAM vegetable or dairy compost treatment contained the above mixture except with 143.2 g

ter content, and a 41% carbon content in the bacterium or fungus (Jenkinson and Ladd 1981). Microbial biomass is the sum of active fungal and bacterial biomass. Microbial biomass / *V. dahliae* biomass (MB / VB) was calculated by dividing microbial biomass by *V. dahliae* biomass.

Statistical Analysis

All dependent variables were tested for normality with univariate procedures. Data were then analyzed by means of ANOVA procedures for a randomized block design with Statistical Analysis Systems (SAS 1996). Residuals were equally distributed with constant variances. Differences were judged significant at = 0.05, as determined by the Least Squares Difference test. Correlations were analyzed with *V. dahliae* infection rating and presence or absence of *V. dahliae* in tissue as dependent (x) variables and *V. dahliae* biomass, microbial biomass, or MB / VB as independent (y) variables.

Results

Since analysis of variance indicated that treatment by soil by interactions for V_{vis} and V_{iso}, plant weight, active bacterial and fungal biomass, total microbial biomass, *V. dahliae* biomass and MB:VB ratio were significant, results will be discussed with regard to treatments in each soil source (Kirk 1982). Soil amended with wood chip PAM cores and wood chip- PAM-vegetable compost cores had lower V_{vis} rates than all other treatments (Table 1). Soil amended with wood chip-PAM-dairy cores and compost soils amended with vegetable compost only had lower V_{vis} and V_{iso} rates than the control soil or soil amended with dairy compost. Plant and tuber weight did not significantly differ among treatments (Table 1). Active fungal and bacterial biomass did not differ consistently with treatment or soil source. Soil 1 in the control treatment had higher *V. dahliae* biomass than all other treatments, except soil 1 in the dairy compost treatment. Wood chip cores in soil amended with dairy compost and vegetable compost had higher *V. dahliae* biomass in soils 1 and 2 than wood chips+PAM alone. The control, vegetable compost and dairy compost treatments had lower MB/VB ratios that the other three treat-

TABLE 1.
Infection ratings, potato biomass, yield, active microbial and *Verticillium dahliae* biomass and the microbial biomass / *Verticillum dahliae* biomass ratio in soil and wood chip and polyacrylamide cores with vegetable and compost treatments.

Treatment	Soil	Infection Rating V_{vis}	Infection Rating V_{iso}	Total Plant Weight g^{-1}	Tuber Weight (Yield) g^{-1}	Soil Active Microbial Biomass Fungal	Soil Active Microbial Biomass Bacterial	Soil Active Microbial Biomass Total	*V. dahaliae* biomass Soil	*V. dahaliae* biomass Chips	MB / VB Soi	MB / VB Core
						$\mu g\ C\ g^{-1}$ Soil						
Control	1	27.1b	0.89a	11.6ab	4.2b	1.6a	3.6b	5.2bc	0.169a	-	30.7c	-
	2	8.1d	1.0a	13.9ab	5.0b	1.7a	3.4ab	4.1bc	0.085b	-	48.2c	-
	3	19.8bc	1.0a	14.1ab	6.9b	0.9a	1.1c	2.0c	0.076b	-	26.3c	-
Wood Chips + PAM	1	4.7e	0.25c	4.5b	1.0b	4.3a	6.3a	10.6a	0.055b	0.008c	192.7a	132.5a
	2	0.0e	0.57b	6.1b	1.1b	6.0a	3.7b	9.6ab	0.048b	0.005c	200.0a	192.0a
	3	0.0e	0.0c	4.4b	0.6b	5.3a	5.5a	10.8a	0.045b	0.057b	240.0a	189.0a
Wood Chips + Vegetable Compost + PAM	1	2.5e	0.16c	8.3b	4.3b	5.4a	4.7ab	10.1a	0.067b	0.060b	150.7a	168.3a
	2	2.7e	0.11c	10.0b	5.4b	5.2a	4.7c	9.9ab	0.053b	0.090a	186.8a	110.0ab
	3	0.0e	0.13c	12.5ab	8.3ab	3.4a	4.6c	8.0ab	0.053b	0.076b	150.9a	105.2b
Wood Chips and Dairy Compost + PAM	1	17.2c	0.56b	11.0ab	6.2b	3.6a	4.8ab	8.4ab	0.080b	0.048b	105.0ab	175.0a
	2	15.6c	0.49b	15.8ab	10.0ab	2.9a	4.6ab	7.5b	0.072b	0.072ab	104.2ab	104.2b
	3	9.5d	0.44b	17.3a	11.9a	2.6a	3.7bc	7.3b	0.069b	0.068ab	105.7ab	107.3b
Vegetable Compost	1	9.4d	0.24c	7.3ab	2.8b	3.1a	3.4b	6.6bc	0.085b	-	77.7b	-
	2	15.2c	0.22c	9.8b	4.0b	2.5a	1.5c	3.7c	0.074b	-	50.0c	-
	3	8.6d	0.00d	10.6b	8.7ab	0.6a	1.4c	2.0c	0.047b	-	70.0b	-
Dairy Compost	1	24.4b	0.67ab	7.9ab	0.5b	3.0a	4.8ab	7.8b	0.101ab	-	77.2b	-
	2	60.3a	1.0a	8.3ab	1.7b	2.2a	2.6bc	4.8c	0.067b	-	71.6b	-
	3	53.4a	1.0a	12.0ab	4.1b	0.9a	1.7c	2.5c	0.050b	-	50.0c	-

V_{vis} = visible *Verticillium dahliae* infection; percent of the plant with visible symptoms of *V. dahliae* infection; V_{iso} = *Verticillium dahliae* infection as measured by isolation; graded as no isolation = 0 and *V. dahliae* isolated = 1; MB / VB = microbial biomass in soil or core / *Verticillium dahliae* biomass in soil or core; In each column, values followed by the same letter are not significantly different as determined by the Least Square Means Test (P 0.05) n=54; - indicates that no cores were present. No cores were present in control, vegetable compost without wood chip - PAM treatments and dairy compost without wood chip - PAM treatments.

(0.32 lb) wood chips and 115.7 g (0.26 lb) vegetable or dairy compost. The three month old soil-dairy or soil-vegetable compost treatments without a core contained 2.7 kg (1.23 lb) soil mixed with 300 g (0.66 lb) dairy or vegetable compost. All soils were then watered to field capacity with well water.

Growing Conditions

Russet Burbank potato tubers were cut into 35 ± 5 g (1.23 oz) seed pieces and planted 4 cm deep in each pot. Potato plants were grown from May 24th to August 25th, 1997 in a greenhouse that was maintained at 26 ± 5°C. Plants were watered with well water to maintain field capacity and were fertilized with Arnon's nutrient solution (Arnon and Hoagland 1940) each week. During that time, the plants were exposed to sunlight with was a photosynthetic active radiation of 400-700 μmol m^{-2} S^{-1} and a 14-16 h photoperiod.

Harvesting and Disease Assessment

At harvest, plants were removed from the pots and separated into roots, shoots, and tubers. Roots and tubers were washed in water and then distilled deionized water until all visible soil particles were removed. Verticillium symptoms, which were wilted and yellowish to brown leaves and stems, were separated from other wilt-producing symptoms in potato plants (drought stress, nutrient deficiency, senescence) by assaying the basal 3 cm of stem tissue for *V. dahliae* (Strausbaugh 1993). *V. dahliae* was isolated from potato plants by slicing a 0.10 cm thick segment from the basal stem of each plant. Segments were surface disinfected for 1 min in 0.5% (v/v) NaOCl, rinsed in sterile distilled water and placed on bacto-agar (Difco laboratories, Detroit, Michigan). Colonies of *V. dahliae* with vertically branched conidiophores and conidia typical of *V. dahliae* formed in and around the vascular tissue in the segments of symptomatic plants (Strausbaugh 1993). Verticillium symptoms were evaluated at termination of the experiment and data were expressed as 1) a percentage of stems with Verticillium symptoms (V_{vis}) and 2), a percentage of plants from which V. *dahliae* was isolated (V_{iso}). All root, shoot, and tuber tissue was then dried at 80C for 48 h and weighed.

Estimation of Verticillium dahliae in Soil

At harvest, soil, cores and plant roots from each pot were separated. Soil and wood chip- PAM or wood chip - PAM - compost amended cores from each pot were collected at harvest and analyzed separately for *V. dahliae*, and other active fungal and bacterial biomass. Soil and core material was collected, stored in air-tight and moisture-tight plastic freezer bags at 4°C and at moisture conditions at harvest. Soil was prepared for estimation of *V. dahliae* and microbial biomass within 24 h of collection to minimize the effects of storage on microbial activity (West *et al.*1986). *V. dahliae* colony forming units (cfus) in soil and in cores were estimated using procedures described by Butterfield and DeVay (1977). *V. dahliae* cfu were converted to *V. dahliae* biomass to be able to compare the amount of *V. dahliae* inoculum to the amount of total fungi and bacteria in the soils and cores. In the conversion from *V. dahliae* cfus to *V. dahliae* biomass, it was assumed that each cfu arose from a piece of *V. dahliae* hyphae or spore able to cause an infection in potato. Previous studies (Lodge and Ingham 1991; Jenkinson and Ladd 1981) have found that a carbon to volume conversion factor of 120 μg carbon mm^{-3}, a 1.1 g cm^{-3} wet density, 20% dry matter content, and a 41% carbon content in fungi is appropriate for hyphal length to fungal biomass. These estimations were used to convert *V. dahliae* colonies to *V. dahliae* biomass.

Microbial Biomass Measurements

Active bacterial and fungal biomass for each soil and wood chip core in each pot at harvest were estimated using direct counting methods as described by Ingham and Klein (1984). A 1.0 g soil sample was diluted in 9 ml of a phosphate buffer (pH 6.0) and shaken at approximately 120 rpm for 5 min. A 1 ml aliquot was removed and stained for 3 min with 1 ml of a 20 g ml^{-1} fluorescein diacetate (FDA) solution in a 0.2 M phosphate buffer. One ml of 1.5% agar in a pH 9.5 0.1 M phosphate buffer was added to the FDA suspension. The sample was mixed and an aliquot placed on a microscope slide containing a cavity of known volume (Ingham and Klein 1984). Slides were examined for FDA-stained hyphal length immediately after preparation by epifluorescent microscopy (Stamatiadis *et al.* 1990). Three fields per slide were evaluated with phase contrast microscopy for total hyphal length, and three transects were evaluated for FDA-stained (active) hyphal length at X1000 total magnification. Using epifluorescent microscopy, 10 fields per slide were evaluated to determine numbers and size of fluorescent bacteria (Lodge and Ingham 1991). Bacterial volume was computed from the number of soil bacteria per gram of soil with the assumption that bacterial spheres were 1 μm in diameter (Jenkinson and Ladd 1981). A carbon to volume conversion factor of 120 μg C mm^{-3} was used for both bacteria and fungi, assuming 1.1 g cm^{-3} wet density, 20% dry mat-

ments. The MB/VB ratios in the vegetable and dairy compost treatments were higher than the control treatment. V_{vis} correlated curvinlinearly with the MB/VB ratio in a negative relationship (r^2=0.76). As the MB/VB ratio increased, visible infection of *V. dahliae* decreased.

Discussion

The major challenge facing commercial production of biological control of plant pathogens is to obtain effective and reproducible disease control. The lack of disease control by organic treatments and biological control products for plant pathogens is often ascribed to environmental factors, which are often difficult to define (Renwick and Poole 1989). In field conditions, fluctuations in moisture, temperature and nutrient and carbon availability can play a role in limiting effectiveness of biological control treatments. Various communities of indigenous microorganisms in any one soil have adapted to the specific environmental conditions. One method of controlling plant pathogens in a soil environment may be to change the soil environment to favor indigenous microorganisms that will out compete plant pathogens. In our greenhouse study, we found that V_{vis} and V_{iso} infection rates were substantially reduced by adding wood chips amended with PAM, with or without dairy or vegetable compost to soils containing high concentrations of *V. dahliae* biomass. Since as the MB/VB ratio increased V_{vis} and V_{iso} rates decreased, competition from indigenous microorganisms may be responsible.

In this experiment, the PAM Superfloc® A836 copolymer was used to loosely adhere indigenous microorganisms to wood chips and potato roots. Several studies found that PAM degradation in soil is fairly rapid (Kay-Shoemake *et al.* 1998a ;1998b; Shanker *et al.* 1990; Lande *et al.* 1979). Enrichment cultures showed that bacteria are capable of utilizing PAM as a sole source of both carbon and nitrogen and that soil microorganisms are capable of utilizing PAM as a sole source of nitrogen, but not carbon (Kay-Shoemake *et al.* 1998a ;1998b). Microbial degradation of PAM on a particular site is likely dependent on soil moisture, temperature, carbon and nutrient status as well as on the amount and type of PAM application. These results indicate that the most likely mechanisms of PAM degradation in soils and water include removal of N by microbial activity and breakage of the linear chain via UV and shear forces in the field (Kay-Shoemake *et al.* 2000a; 2000b). Changing the soil environment by adding green manure crops (Davis *et al.* 1996) and nutrient relationships (Davis *et al.* 1994a) has been shown to limit early dying in potato. We found that soil amended with vegetable compost, but not with dairy compost, increased the MB/VB ratios and reduced *V. dahliae* infection rates. Simply adding vegetable compost or proper nutrient management may be able to reduce *V. dahliae* infection on potato. However, amending the soil with wood chip-PAM or wood chip-PAM-vegetable compost mixture further reduced *V. dahliae* infection.

The water soluble PAMs studied are used in erosion control and are very large anionic molecules. In industry they are used safely for a variety of food, water treatment and sensitive environmental applications (Barvenik 1994). They should not be confused with gel forming, crosslinked PAM, or evaluated with other PAM formulations, especially cationic PAMs, which have known safety concerns related to their specific chemistries (Barvenik 1994). Environmental regulation, safety and toxicity issues related to PAM use have been extensively reviewed (Barvenik 1994). Polyacrylamide compounds are used in many industrial processes to accelerate flocculation or at high concentrations as lubricants or sealing or suspending agents. Used at prescribed rates, anionic PAMs are environmentally safe. Negative impacts have not been documented for aquatic macrofauna, edaphic microorganisms, or crop species for the anionic PAMs used for erosion control when applied at recommended concentrations and rates Kay-Shoemake (1998a; 1998b). In a recent study, Sojka *et al.* (2005) measured active soil bacterial and fungal biomass and microbial diversity in soils receiving 0 (control), 2691 and 5382 kg active ingredient (ai) PAM ha^{-1}. They found that active bacterial biomass in soil was 25-40% greater in the control treatment than in soil treated with 2691 or 5382 kg ai PAM ha^{-1} in June and August, but not July. Active fungal biomass in soils was 50-200% greater in the control treatment than soil treated with 2691 or 5382 kg ai PAM ha^{-1} in June and July, but not August. Active microbial biomass in soil was 27-48% greater in the control treatment than soil treated with 2691 or 5382 kg ai PAM ha^{-1} except in June. Whole soil fatty acid profiles showed no discernible change in the soil microbial community due to either of the PAM treatments at any sampling time. Analysis of nutritional characteristics using BIOLOG GN plates, however, yielded an apparent separation of the nonamended control soils from those plots receiving the high PAM application rate in June, but not in July or August. In contrast, comparisons of the three sampling times by both the fatty acid and BIOLOG analyses indicated that the microbial communities present in June were different from those sampled in July and August. Spackman *et al.* (2003) found that 10 mg PAM ha^{-1} did not affect concentrations of total or fecal coliform

bacteria in irrigation water, soil water or soils in the presence of a dense grass stand acting as a filterstrip. Nitrification of added urea appears to be somewhat accelerated (approximately 10% over 2 weeks) in PAM- treated microcosm soils (Kay-Shoemake *et al.* 2000b), but no other significant impacts of PAM-application on fertilizer fate have been noted. Sorptive dynamics of the common pesticides, 2,4-D and atrazine, are not dramatically altered by PAM treatment of field soil samples, although some slight changes in desorption and degradation rates were reported (Watwood and Kay-Shoemake 2000a). Even at very high concentrations, when PAMs are introduced into waters containing sediments, humic acids or other impurities, PAM effects on biota are greatly buffered due to adsorption and deactivation associated with the suspended impurities (Goodrich *et al.* 1991; Buchholz 1992). Watwood *et al.* (2000b) found that although PAM additions to field soils do correlate with discernable changes in microbial carbon utilization patterns, these effects are masked by impacts of other field variables, such as crop cover type or nutrient status.

A wood chip-PAM core was practical for a greenhouse study; however, when growing potatoes on a commercial basis, adding a wood chip-PAM core when planting would probably be impractical. A practical method might be to make a shallow trench adding the wood chip- PAM mixture in the same pass or soon after. Although field studies with potato and other crops and economic evaluations are necessary, amending soil with wood chips-PAM or wood chips- PAM-vegetable compost mixtures might be valuable methods to control some soilborne diseases. The use of wood chip-PAM-vegetable compost treatments may be a possible method to control soilborne diseases in high value crops. Methyl bromide is a widely used fumigant in the commercial production of strawberries (*Fragaria chiloensis* D.) , tomatoes (*Lycopersicon esculentum* L.), peppers (*Capsicum* sp.), melons (*Citraullus vulgaris* Schrad. and *Cucumis melot* L.), cucumbers (*Cucurbita sativus* L. and *Cucurbita anguria* L.), and various ornamentals (Ragsdale and Wheeler 1995; Ristanio and Thomas 1997). Evidence has accumulated that methyl bromide is implicated in the destruction of stratospheric ozone (WMO 1994) and the compound is scheduled to be phased out of production and use by the year 2005 (US EPA 1993). Other currently available fumigants such as methyl iodide, Vorlex (1,3- dichloropropene, and methyl isocyanate), Vapam (metam sodium), Telone [1,3- dichloropropene and Basmid (dazomet)] cost more, have reduced efficacy and higher toxicity compared to methyl bromide (Ragsdale and Wheeler 1995; Ristanio and Thomas 1997). It has been estimated that economic losses to producers in the United States from phasing out fumigation of soils with methyl bromide will be $800-$900 million, the greatest losses occurring in tomato and strawberry production (USDA 1993). Our study provides some evidence that changing the soil environment to favor biological control or indigenous soil microorganisms to control soil pathogens may give producers an alternative to soil fumigants.

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