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PEST AND DISEASE MANAGEMENT IN ORGANIC FARMING

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Health status of spring barley cultivated under organic, integrated and conventional farming conditions

A Baturo
University of Technology and Agriculture, Faculty of Agriculture, Department of Phytopathology, Kordeckiego 20, 85-225 Bydgoszcz, Poland
E-mail: baturo-a@atr.bydgoszcz.pl

ABSTRACT

Roots, stem bases and harvested grain of spring barley cultivated in organic, integrated and conventional systems were compared. The worst plant health status was observed in the organic system, especially in the case of stem base samples. The most important diseases of spring barley roots and stem bases were *Bipolaris sorokiniana* and fungi from the *Fusarium* genus. *Bipolaris sorokiniana* occurred in significantly higher intensity in the organic system and *Fusarium* spp. in the integrated and conventional systems. The higher occurrence of *B. sorokiniana* on harvested grain in the organic system indicates that it might not be suitable for use as seeds. However, the lower occurrence of *Fusarium* spp. in the organic system is advantageous from a nutrition point of view because of its abilities to produce mycotoxins.

INTRODUCTION

Consumers are becoming interested in the origin and methods used in the production and processing of their food and this has lead many farmers to adopt integrated or organic farming methods. There is very little detailed information about the mycological quality of organic produce, which is commonly recognised as having a high dry matter and vitamin content and an absence of pesticide residues. It is also claimed that organic food may play a role in the prevention of allergies or cancers. However, some research results indicate that it can be infected by pathogenic microorganisms such as fungi or contain harmful substances like mycotoxins (Marckmann, 2000; Trewavas, 2001). The research reported here aimed to evaluate the impact of different farming systems on the health of spring barley crops and to compare the occurrence of the main crop pathogens, including *Bipolaris sorokiniana* and *Fusarium* spp., in these systems. The intention of this paper is to show general trends in the development of these pathogens and the extent of their presence in spring barley in the three different farming systems.

MATERIALS AND METHODS

The studies were carried out from 1998-2001 on experimental fields at Osiny in south-eastern Poland. The research variety was spring barley, cv. Rudzik. Crops in the integrated and conventional systems were chemically treated at recommended rates.

Macroscopic evaluation of plant health status and mycological analyses were carried out at two crop stages: at emergence and at the beginning of dough maturity. At emergence, four replicates of 50 plants were sampled randomly from each field and root and stem base infestation was evaluated. At dough maturity four replicates of 25 plants were sampled from each field. Besides root and stem bases, head infestation was also evaluated. Additionally, in 2000-2001, in order to determine the cause of infection, 30 heads with disease symptoms were put on wet blotting paper on 140 mm plates, and incubated at 23°C. After 5 days, the pathogens were identified, based on conidia, using a microscope.

At both crop stages, root and stem base infestation was evaluated on a 0-5 scale from 0 (healthy roots or stem bases) to 5 (roots with > 70% area damaged or stem bases rotted completely). At the dough stage head infestation was evaluated on a 0-6 scale - from 0 (healthy heads) to 6(> 50% of head surface infected). The level of infestation was transformed to a disease index (DI) according to Townsend`s and Heuberger`s formula (Wenzel 1948). The obtained data were analysed statistically by ANOVA and a Tukey test used to compare means.

At both crop stages, and during evaluation of infestation, plants with disease symptoms on roots and stem bases were separated and prepared for mycological analysis. Fragments of roots and stem bases were washed for 40 minutes under running tap water, and then three times with sterile water, before putting them onto the PDA medium at pH 5.5. Six fragments were put on one dish. Petri dishes, with experimental material were incubated at 23°C. Fungus colonies were transferred to test tubes with PDA medium and then, if necessary, put on Petri dishes with Czapek Dox, PDA or SNA mediums. After an appropriate time fungi were identified using according to mycological keys. From 1998 – 2001 four harvested 100 grain samples from each system were also subject to the same mycological analysis.

RESULTS

Mean level of DI on roots at emergence was higher in organic systems compared to conventional or integrated systems. In contrast, at the dough maturity stage, higher DI was observed in the conventional system compared to the other two systems (Table 1). Mycological analysis of roots showed *B. sorokiniana* and *Fusarium* spp. to be present. At emergence *B. sorokiniana* was the main cause of disease symptoms. However at the dough maturity stage *Fusarium* spp. were the main species isolated. In both stages *B. sorokiniana* was present at similar intensity in the conventional and organic systems while *Fusarium* spp. were more prevalent in the organic system (Table 2).

Stem bases were significantly more infected in the organic system at both crop stages (Table 1). At emergence the main cause of disease were *Fusarium* spp. Their presence was the highest in the integrated system. *Bipolaris sorokiniana* was more prevalent in the organic system. At dough maturity *B. sorokiniana* was the main cause of disease and was present at highest intensity in the organic system. The conventional system was especially favourable to *Fusarium* spp. (Table 2).

Head infestation was similar in all three systems. However *B. sorokiniana* was the main cause of infection in the organic system, while *Fusarium* spp. was the main cause in integrated and conventional systems (Table 1 and Figure 1). The grain mycological analyses confirmed the presence of these species and these tendencies (Table 3).

Table 1. Disease index on roots, stem bases and heads, 1999-2001.

Farming system	Roots		Stem bases		Heads
	emergence	dough maturity	emergence	dough maturity	
Organic	1.7 a*	4.3 b	8.4 a	36.8 a	7.3 a
Integrated	0.7 b	4.8 b	1.4 b	20.9 b	5.7 a
Conventional	0.5 b	12.3 a	0.8 b	23.3 b	7.1 a

* values in the same column followed by different letters are significantly different

Table 2. Proportion (% of total number of fungi observed) of *B. sorokiniana* and *Fusarium* spp. isolated from roots and stem bases at emergence and the beginning of dough maturity stages in organic (O), integrated (I) and conventional (C) farming systems,1999-2001.

Fungus	Roots						Stem bases					
	emergence			dough maturity			emergence			dough maturity		
	O	I	C	O	I	C	O	I	C	O	I	C
B. sorokiniana **(Sacc. in Sorok) Shoem.**	**27.5**	**12.0**	**30.0**	**8.5**	**4.5**	**8.2**	**34.2**	**18.2**	**12.1**	**43.1**	**21.7**	**10.8**
F. avenaceum (Corda ex Fr.) Sacc.	2.5	-	-	3.2	2.7	-	16.7	9.1	6.1	3.4	7.6	12.7
F. culmorum (W. G. Smith) Sacc.	-	-	-	1.1	1.8	5.9	1.8	1.8	12.1	2.6	9.8	5.9
F. equiseti (Corda) Sacc.	-	-	-	-	0.9	-	0.9	-	-	2.6	1.1	8.8
F. graminearum Schwabe	-	-	-	-	-	-	2.6	-	-	0.9	5.4	4.9
F. oxysporum Schlecht.	10.0	4.0	10.0	18.1	12.7	11.8	16.7	18.2	12.1	4.3	1.1	6.9
F. poae (Peck.) Wollenweber	-	-	-	-	-	-	-	-	-	0.9	1.1	7.8
F. reticulatum Mont.	-	-	-	-	-	-	-	-	-	0.9	-	-
F. solani (Mart.) Sacc.	5.0	4.0	-	21.3	17.3	17.6	3.5	18.2	3.0	3.4	4.3	-
F. tricinctum Corda	-	-	-	-	-	-	-	5.5	6.1	-	-	-
Fusarium spp.	-	-	-	-	-	-	-	-	-	5.2	-	5.9
total number of *Fusarium* spp.	**17.5**	**8.0**	**10.0**	**43.7**	**35.4**	**35.3**	**42.2**	**52.8**	**39.4**	**24.1**	**30.4**	**52.9**

Table 3. Grain infected (%) by *B. sorokiniana* and *Fusarium* spp. in organic (O), integrated (I) and conventional (C) farming systems in 1998-2001

system	*Bipolaris sorokiniana*	*Fusarium avenaceum*	*Fusarium culmorum*	*Fusarium graminearum*	*Fusarium poae*	*Fusarium tricinctum*
O	65.3	5.8	1.0	1.8	15.3	0.3
I	7.8	28.8	3.5	6.0	30.2	4.3
C	16.8	22.3	4.8	3.8	32.5	7.0

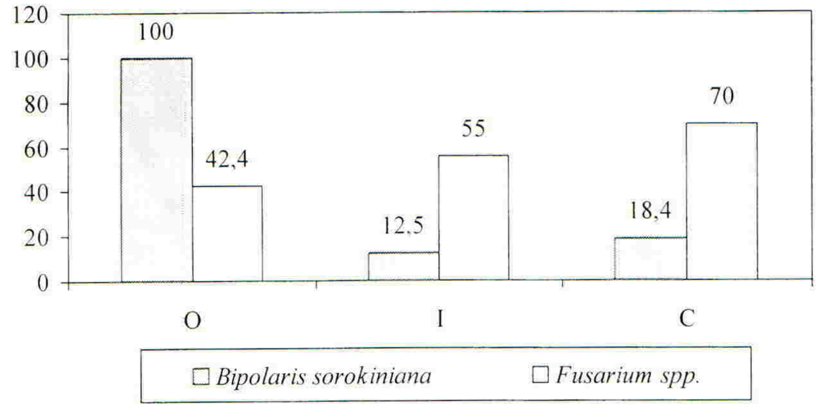

Figure 1. The percentage of heads with disease sympthoms caused by *B. sorokiniana* and *Fusarium* spp. at the beginning of dough maturity stage in organic (O), integrated (I) and conventional (C) farming systems in 1999-2000.

DISCUSSION

Based on the data obtained in this work it seems that the health status of spring barley during the cropping season was dependent on farming system. *Bipolaris sorokiniana* and fungi from the *Fusarium* genus clearly influenced plant health. Higher root infestation was observed in the conventional system and a clear correlation between plant health status and *B. sorokiniana* and *Fusarium* spp. as a cause of disease symptoms was observed. Stem bases and harvested grain were significantly more infected in the organic system and the main cause was *B. sorokiniana*. This confirms other observations made on organic and conventional farms by Baturo-Czajkowska *et al.* (1998) and Baturo (2002). In the integrated and conventional systems higher levels of *Fusarium* spp. were isolated from stem bases and grain confirming observations made in winter wheat by Lukanowski, *et al.*, (2001) and Kus & Mroz (2000) who found higher incidence of *Fusarium* spp. in conventional and integrated systems than in organic ones.

Mycological analyses showed that one of the main causes of disease were *Fusarium* spp. They are considered as one of the most important cereal pathogens causing disease heads and grain and, often, seedling damage (Mathre, 1987). According to Tahsein & Amein (1988) seed treatment is only partially able to limit plant infection. The higher intensity of *Fusarium* spp. in conventional and integrated systems confirms that using chemically treated grain doesn't guarantee healthy crop plants. *Fusarium oxysporum,* which is not harmful for cereals, was the main species isolated from roots and stem bases, whilst the species *F. culmorum* and *F. graminearum*, which are harmful, where isolated less frequently. These fungi could also be dangerous due to their abilities to produce mycotoxins (Chelkowski, 1994; D`Mello, *et al.*, 1999; Doohan *et al.* 2000; Manka, 1989). Trewavas (2001) claims that contamination by mycotoxigenic fungi and mycotoxins can be higher in organic products than in conventional ones. The results presented here don't confirm this hypothesis in the case of *Fusarium* spp. Besides *Fusarium* spp., *Bipolaris sorokiniana* was commonly isolated, especially in the organic system. This pathogen is considered as a major disease of barley, which is transmitted in the seed (Christensen, 1963). For this reason organically produced sowing material could be potentially detrimental. *Bipolaris sorokiniana* limits germination drastically and the yield from plants with diseased roots, stem bases, leaves and heads can be reduced by at least 30% (Eng Chong Pua, *et al.*, 1985; Lacicowa & Pieta, 1993).

SUMMARY

This study has shown that spring barley health status is dependent on farming system. Although a higher root infection was observed in the conventional system, generally plants, and especially stem bases, were significantly more diseased in the organic system. *Bipolaris sorokiniana* and fungi from the *Fusarium* genus are the most important disease threat to root, stem bases and grain health. The former was isolated more often in the organic system, while the latter was observed more often in the conventional and integrated systems. This suggests that conventional or integrated spring barley cultivation can limit *B. sorokiniana* but can be favourable to *Fusarium* spp. as was clear in the case of harvested grain. The use of own saved seed on organic farms could represent a threat to plant health due to the presence of *B. sorokiniana*, which significantly limits germination and can have a great impact on seedling and older plant vigour. However, *Fusarium* spp. that can produce dangerous mycotoxins, where not found at greater levels in organic systems.

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REFERENCES

Baturo A (2002). Phytopathological aspect of fungi communities occurring on spring barley and its rhizosphere in organic, integrated and conventional farming systems. Doctoral thesis, University of Technology and Agriculture in Bydgoszcz, Poland.

Baturo-Czajkowska A; Czajkowska I; Sadowski C (1998). Comparison of *Bipolaris sorokiniana* Sacc. infestation of spring barley cultivated in ecological and conventional farming systems. In: *Mat. IX Conference: Biological agents and their effectiveness in the control of plant pathogens, Skierniewice, Poland*, 195-199.

Chelkowski J (1994). Significance of *Fusarium* metabolites in interaction between a cereal plant and a pathogen. *Genetica Polonica* **35B**, 137-142.

Christensen J J (1963). Longevity of fungi in barley kernels. *Plant Disease Reporter* **47**, 639-642.

D'Mello J P F; Placinta C M; Macdonald A M C (1999). *Fusarium* mycotoxins: a review of global implications for animal health, welfare and productivity. *Animal Feed Science and Technology* **80,** 183-205.

Doohan F M; Mentewab A; Nicholson P (2000). Antifungal Activity Towards *Fusarium culmorum* in soluble wheat extracts. *Phytopathology* **90**, 666-671.

Eng-Chong Pua R R; Pelletier H R; Klinck H R (1985). Seedling blight, spot blotch and common root rot in Quebec and their effect on grain yield in barley. *Canadian Journal of Plant Pathology* **7**, 395-401.

Kus J; Mroz A (2000) Stan fitosanitarny i plonowanie pszenicy ozimej w różnych systemach produkcji roślinnej. *Rocz. AR Poznań CCCXXI, Ogrodnictwo* **30**, 69-76.

Lacicowa B; Pieta D (1993). The effect of recurrent cropping on stem and root diseases and grain yield of spring barley (*Hordeum vulgare* L.). *Roczniki Nauk Rolniczych* **23** (1/2), 21-25.

Lukanowski A; Baturo-Czajkowska A; Sadowski Cz (2001). Health status of cereals cultivated in different systems with a special respect to ecological cultivation. *IOBC/WPRS Bulletin* **24 (1)**, 101-106.

Manka M (1989). Patogeniczność wybranych gatunków z rodzaju *Fusarium* dla siewek zbóż. *Roczniki AR* w Poznaniu, Rozprawy Naukowe 201.

Mathre D E (1987). Compendium of barley diseases. The American Phytopathological Society: St. Paul, USA

Marckmann P (2000). Organic foods and allergies, cancers and other common diseases – present knowledge and future research. In: *Proceedings 13 th IFOAM International Scientific Conference in Basel*, eds Alfoldi T, Lockeretz W and Niggli U, p312. FiBL: Frick, Switzerland.

Tahsein A; Amein M (1988). Wpływ chemicznego zaprawiania ziarna na ograniczenie porażenia korzeni i podstawy źdźbła pszenicy przez *Gaeumannomyces graminis* var. *tritici* oraz grzyby z rodzaju *Fusarium*. *Roczniki Nauk Rolniczych*, seria E, t.**18** (2), 162-168.

Trewavas A (2001). Urban myths of organic farming. *Nature* **410**, 409-410.

Wenzel H (1948). Zur Erfassung des Schadenausmasses in Pflanzenschutzversuchen. *Pflanzenschutz-Ber.* **15**, 81-84.

Management of plant parasitic nematode populations by use of vermicomposts

N Q Arancon, C A Edwards, S S Lee
The Ohio State University, 1735 Neil Avenue, Columbus, OH 43210 USA
Email: arancon.1@edu.osu

E Yardim
Yuzuncu Yil Universitesi , Bitki Koruma Bolumu, Van, Turkey

ABSTRACT

Commercial vermicomposts, produced from cattle manure, food and recycled paper wastes, were applied at rates of 5 t/ha, 10 t/ha and 20 t/ha, to field plots planted with tomatoes (*Lycopersicon esculentum*) bell peppers *(Capsicum annum grossum*), strawberries (*Fragaria ananasa*) or grapes (*Vitis vinifera*). Control plots were treated with inorganic fertilizers only, and all vermicompost-treated plots were supplemented with inorganic fertilizers, to equalize levels of available N in all plots. Nematodes populations were estimated by after extraction in Baermann funnels and nematodes were identified and classified to trophic level. Populations of plant-parasitic nematodes were depressed significantly by the three vermicomposts in all four field experiments compared with those in plots treated with inorganic fertilizer. Conversely, populations of fungivorous and bacterivorous nematodes tended to increase consistently compared with those in the inorganic fertilizer-treated plots.

INTRODUCTION

There has been a growing interest in finding ways of decreasing the use of inorganic fertilizer and pesticides in agricultural production. These include adoption of new crop varieties that use soil nutrients more efficiently and better use of organic matter. The use of organic amendments, like traditional thermophilic composts, has been long recognized as an effective means of improving soils, increasing plant growth and yields, and suppressing plant diseases. Vermicomposts are a new form of organic soil amendment that have considerable potential in crop production. Vermicomposts are finely divided peat-like materials with high porosity, aeration, drainage, water-holding capacities, and low C:N ratios produced from organic wastes stabilized by interactions between earthworms and microorganisms (Edwards, 1998). They contain nutrients such as nitrates, exchangeable calcium, phosphorus, and soluble potassium that are taken up readily by plants. Vermicomposts have large surface areas that provide many microsites for microbial activity and for the strong retention of nutrients. Additionally, vermicomposts have been reported to have outstanding biological properties and have microbial populations that are significantly larger and more diverse compared with those of conventional thermophilic composts (Edwards, 1998). The considerable improvements in plant growth recorded after amending soils with vermicomposts have been attributed to the physico-chemical and biological properties of vermicomposts. However, there is now considerable evidence that other biological factors are involved which cause plants to germinate and grow better (Edwards, 1998). Applications of vermicomposts have been reported to suppress plant diseases such as

Phytophthora, *Fusarium*, and *Plasmodiophora* in tomatoes and cabbage, *Pythium* and *Rhizoctonia* in cucumber and radish and *Verticillium* in strawberries (Chaoui, *et al.*, 2002). A comprehensive review concluded that various forms of organic matter amendments can often suppress plant parasitic nematode populations (Addabdo, 1995). Our experiments were designed to assess whether vermicomposts possess properties which suppress plant parasitic nematode populations.

MATERIALS AND METHODS

Vermicompost treatments

Plots were replicated for each treatment with one of three different types of vermicompost. Commercial cattle manure, food and paper waste-based vermicomposts were applied at rates of 20 and 10 t/ha to tomatoes and peppers. Food waste and paper waste-based vermicomposts were applied at 10 and 5 t/ha to strawberries and grapes. One set of replicate plots received a full recommended rate of inorganic fertilizer for all crops. A second set received recommended rates of traditional leaf composts in the tomato and pepper experiments. The grape experiment had one set of replicated control plots treated with the full recommended rates of inorganic fertilizer and another with no fertilizer. All of the vermicompost- and compost-treated plots were supplemented with inorganic fertilizers, in order to balance the initial nutrient supply as far as possible with that in the inorganic fertilizer treatment (except for the unfertilized control). Vermicomposts, composts and inorganic fertilizers were incorporated into the top 15 cm of the beds in the tomato, pepper and strawberry plots with a roto-tiller and vermicompost treatments were surface-applied and covered with straw mulch in the grape plots.

Test crops

Tomato seedlings (var. BHN 543 F1) were transplanted into a single row in each bed measuring 1.5 x 5.5 m (8.25 m^2 per plot) with 38 cm between plants, totaling 12 four-week-old seedlings in each raised bed. Plastic mulch and drip irrigation systems were constructed over the raised beds after vermicompost and fertilizer applications. Plants were staked 4 weeks after transplanting and tied to a twine trellis accommodating 2 plants between stakes. Suckers were removed up to the one below the first flower cluster. All treatments were replicated four times in a randomized complete block design. Guard rows measuring 1.5 x 5.5 m (8.25 m^2 per plot) were set between each block.

Pepper seedlings (var. 'King Arthur'), 24 four-weeks-old, were transplanted into two rows in each raised bed measuring 1.5 x 5.5 m (8.25 m^2 per plot). Seedlings were planted in a staggered pattern relative to plants in the other row spaced 38 cm between plants and 38 cm between rows. Plastic mulch and drip irrigation systems were constructed over the raised beds. Treatments were replicated four times in a randomized complete block design. Guard rows measuring 1.5 x 5.5 m (8.25 m^2 per plot) were set between each block

Strawberry seedlings (var. 'Chandler') were grown under a high plastic tunnel hoop house structures measuring 9.14 x 14.6 x 3.6 m. Twenty-four six-week-old seedlings were transplanted into each plot (4.5 m^2) spaced 38 cm between plants with three rows spaced 38 cm between rows. Plants in the middle row were planted in a staggered design with respect to the outer rows to maximize distances between plants. Plastic mulch, mini-sprinklers and drip irrigation systems were constructed over the raised beds after vermicomposts and fertilizer applications. Cotton mesh row covers were used for frost protection. Treatments were replicated four times in a completely randomized design. There were guard rows (1.5 wide x 12 m) around the perimeter of the experiment.

Grape vines (var. Seyval) were used in the grape experiment. Each plot measured 1.5 X 3 m (4.5 m^2/plot) and contained three 10-year-old vines. Treatments were replicated 8 times in a randomized complete block design.

Assessment of nematode populations

Eight soil core samples, 2.5 cm diameter x 20 cm deep, were taken randomly from each replicate plot. The samples were taken from the root zones of tomatoes, peppers, strawberries and grapes at the end of the growing season. Nematodes were extracted for 48 hours from 20g subsamples per plot, with 3 replicates, using a Baermann funnel extraction method (McSorley & Welter, 1991). Nematodes were identified and classified to trophic level under a stereomicroscope. Grouped means comparisons were made, using orthogonal contrasts, to separate statistical differences between nematode population means in inorganic fertilizer controls, thermophilic composts and vermicompost treatments using SAS statistical package (SAS Ins., 1990).

RESULTS

The effects of vermicomposts on populations of plant parasitic nematodes are summarized in Figure 1, those on fungivorous nematodes in Figure 2 and those on bacterivorous nematodes in Figure 3. Populations of plant parasitic nematodes in all of the vermicompost-treated soils were suppressed significantly for all crops ($P < 0.01$) compared to those in plots treated with inorganic fertilizers only. Populations of plant parasitic nematodes were larger in plots treated with inorganic fertilizer than in those to which no fertilizer was applied. The populations of bacterivorous and fungivorous nematodes were significantly larger in response to most of the vermicompost treatments, compared to those in plots treated with inorganic fertilizer, in the strawberry and grape experiments. There were also increases that were not statistically significant in tomatoes and peppers. The effects did not appear to be correlated with the application rates or type of vermicomposts. Populations of fungivorous and bacterivorous nematodes in the unfertilized grape plots were significantly smaller than those in plots treated with vermicomposts and were similar to those in the inorganic fertilizer plots.

DISCUSSION

The addition of all of the various types of vermicomposts, to the soils in all four experiments, suppressed significantly populations of plant parasitic nematodes (Figure 1). Similar suppressions were reported in a review that concluded that additions of various composted or other types of organic matter to soils often decreased populations of plant parasitic nematodes (Addabdo, 1995).

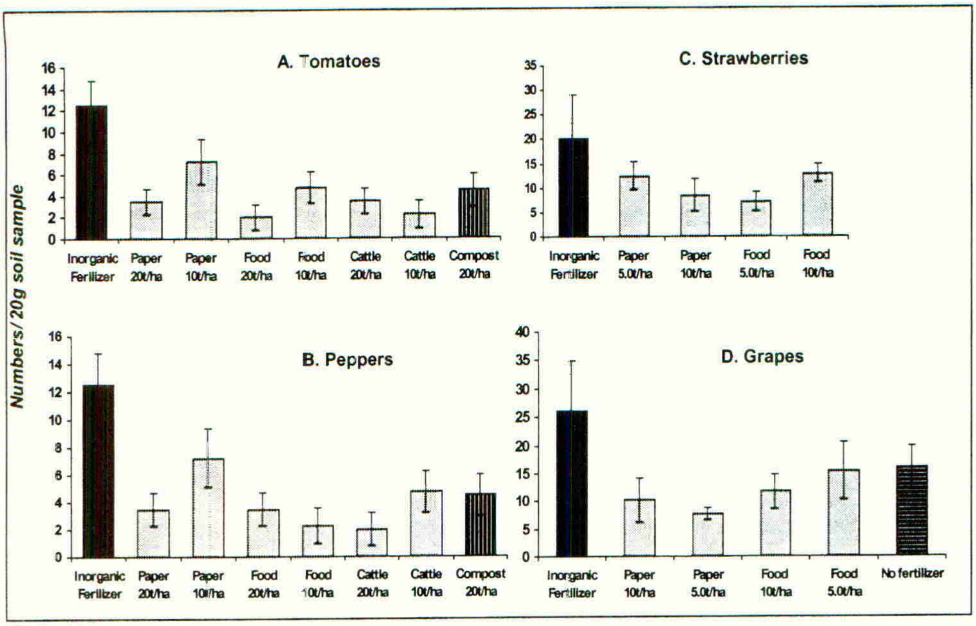
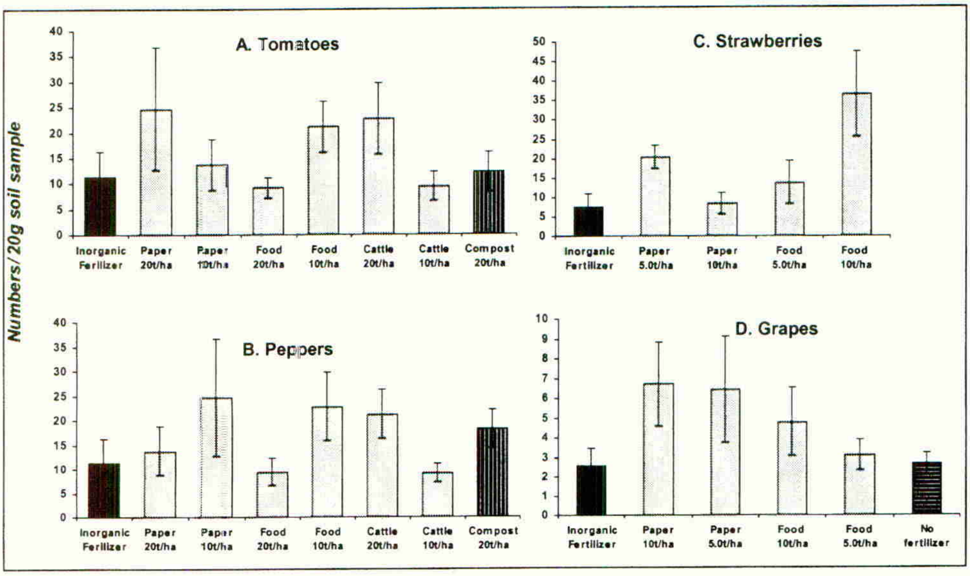


Figure 1: Numbers (Means ± SE) of plant parasitic nematodes in inorganic fertilizer-treated (■), vermicompost-treated (□), compost-treated (◫) and unfertilized (☰) soils planted with tomatoes (A), peppers (B), strawberries (C), and grapes (D).



Figures 2: Numbers (Means ± SE) of fungivorous nematodes in inorganic fertilizer-treated (■), vermicompost-treated (□), compost-treated (◫) and unfertilized (☰) soils planted with tomatoes (A), peppers (B), strawberries (C), and grapes (D).

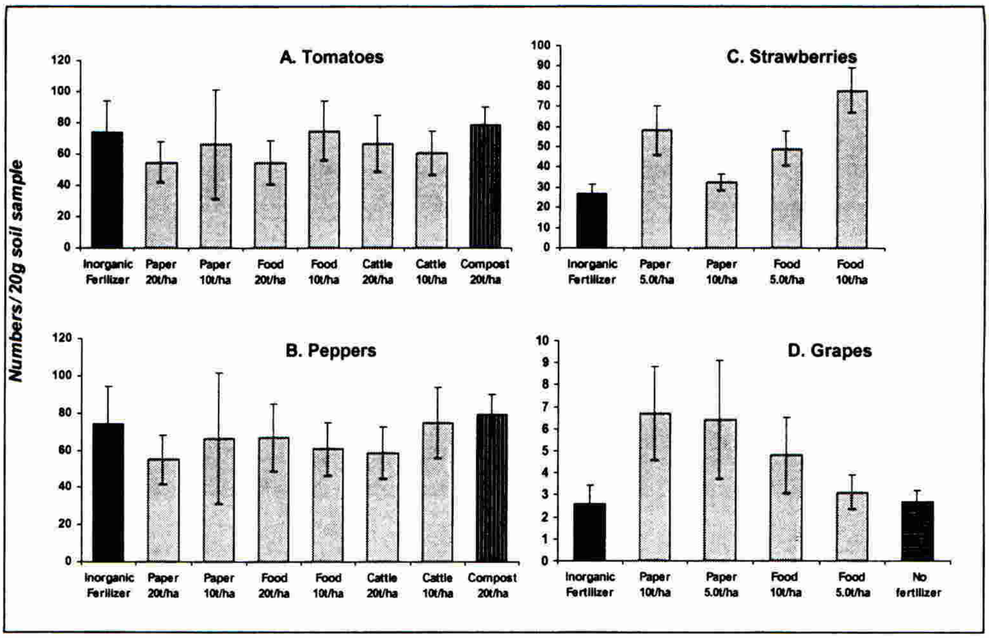


Figure 3. Numbers (Means ± SE) of bacterivorous nematodes in inorganic fertilizer-treated (■), vermicompost-treated (□), compost-treated (▥), and unfertilized (▤) soils planted with tomatoes (A), peppers (B), strawberries (C), and grapes (D).

There are also numerous reports that traditional thermophilic composts can suppress populations of plant parasitic nematodes e.g. McSorley & Gallaher (1995). We recorded similar suppression of plant parasitic nematode populations by vermicomposts in soils planted with tomatoes, peppers, strawberry and grapes (Figs. 1 A, B, C, D). There are a few preliminary reports of vermicomposts suppressing populations of plant parasitic nematodes. Swathi *et al*., (1998) demonstrated that 1 kg/m^2 of vermicompost suppressed attacks of *Meloidogyne incognita* on tobacco plants. Morra et al. (1998) demonstrated partial control of *Meloidogyne incognita* by vermicomposts in a tomato-zucchini rotation. Ribiero et al. (1998) reported that vermicomposts decreased the numbers of galls and egg masses of *Meloidogyne javanica*. The mechanisms by which vermicomposts and composts suppress plant diseases and plant parasitic nematodes are still speculative but it may be due to increased competition from fungivorous and bacterivorous nematodes resulting from increased availability of food sources after vermicompost and compost applications. There is good evidence (Edwards, 1998) that earthworms greatly increase overall microbial activity in organic wastes greatly by providing fragmented organic materials for microbial growth of soil bacteria and fungi. Soils that were treated with inorganic fertilizers only had much less organic matter available for microbial growth compared to those in the vermicompost-treated soils.

The effects of applications of vermicomposts to soils were much greater on fungivorous nematode populations than on bacterivorous nematode populations. Earthworms depend upon fungi as a main source of food and tend to increase fungal activity in their casts by excreting fungal spores (Edwards & Fletcher, 1988) which may also explain why there were greater increases in populations of fungivorous nematodes than in those of bacterivorous nematodes. Moreover, plant parasitic nematodes are attacked by cyst fungi and nematode-trapping fungi populations of which could have increased in response to vermicompost applications (Kerry, 1988). The greater availability of microorganisms as a source of energy could increase the competitive ability of both bacterivorous and fungivorous nematodes as compared to plant parasitic nematodes.

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REFERENCES

Addabdo T D (1995). The nematicidal effect of organic amendments: a review of the literature 1982-1994. *Nematologia Mediterranea* **23**, 299-305.

Chaoui H; Edwards C A; Brickner A, Lee S S; Arancon N Q (2002). Suppression of the plant parasitic diseases: *Pythium* (damping off), *Rhizoctonia* (root rot) and *Verticillium* (wilt) by vermicompost. *Proceedings Brighton Crop Protection Conference –Pest and Diseases* (in press – this volume).

Edwards C A (1998). Breakdown of animal, vegetable and industrial organic wastes by earthworms. In: *Earthworm Ecology*, ed C A Edwards, pp 237-354. CRC Press/Lewis: Boca Raton, Florida.

Edwards C A; Fletcher K E (1988). Interactions between earthworms and microorganisms in organic matter breakdown. *Agriculture, Ecosystems and Environment*, **20** (3), 235-249.

Kerry B (1988). Fungal parasites of cyst nematodes. In: *Biological Interactions in Soil*, eds. C A Edwards, B R Stinner, D Stinner, S Rabatin, pp. 293-306. Elsevier: Amsterdam.

McSorley R; Gallaher R N (1995). Effect of yard waste compost on plant parasitic nematode densities in vegetable crops. *Journal of Nematology* **27**, 245-249.

McSorley R; Welter E E (1991). Comparison of soil extraction method for nematodes and micro-arthopods. In: *Modern Techniques on Soil Ecology*, ed D A Crossly, D C Coleman, P F Hendrix, W Cheng, D H Wright, M H Beane, C A Edwards, pp. 201-208 Elsevier: New York.

Morra L; Palumbo A D; Bilotto M; Ovieno P; Picascia S (1998). Soil solarization: organic fertilization and grafting contribute to build an integrated production system in a tomato-succhini sequence. *Colture-Protte* **27**(7), 63-70.

Ribeiro C F; Mizobutsi E H; Silva D G; Pereira J C R; Zambolim L (1998). Control of *Meloidognye javanica* on lettuce with organic amendments. *Fitopatologia Brasileira* **23**, 42-44.

SAS Institute. 1990. *SAS Procedures Guide*. Version 6, Third Edition. SAS Institute, Cary.

Swathi P; Rao K T; Rao P A (1998). Studies on control of root-knot nematode *Meloidogyne incognita* in tobacco miniseries. *Tobacco Research* **1**, 26-30.

Suppression of the plant diseases, *Pythium* (damping-off), *Rhizoctonia* (root rot) and *Verticillium* (wilt) by vermicomposts

H Chaoui, C A Edwards*, A Brickner, S S Lee, N Q Arancon
Ohio State University, Soil Ecology Laboratory, 1735 Neil Avenue, Columbus, OH 43210 USA
* *Email: soilecol@osu.edu*

ABSTRACT

Vermicomposts are stabilized, non-thermophilic materials produced from organic wastes by interactions between earthworms and microorganisms. Suppression of *Pythium* by vermicomposts was tested by substituting 0, 10, 20 and 40% of vermicomposts (by volume) into 100, 90, 80 and 60% of a soil-less plant growth medium Metro Mix 360 (MM360), inoculated with *Pythium* at a rate of 1:4000 by volume. Disease severity was rated after 10 days, from 1 (symptomless) to 4 (heavy). The disease severity rating was 3.4 in 0% vermicompost substitution, compared with 1.1 in 10% substitution, 1.3 in 20% substitution, and 1.1 in 40% substitution. A similar range of substitutions of sterilized or non-sterilized MM360 and vermicompost was tested in three experiments with radish seeds inoculated with 1:2000 or 1:667 by volume of *Rhizoctonia*. Suppression of *Rhizoctonia* by vermicomposts was correlated progressively with increasing rates of substitution of vermicompost in three experiments. In field experiments planted with strawberries, the incidence of *Verticillium* wilt was suppressed significantly by the application of 5 t/ha and 10t/ha of commercial paper and food waste vermicomposts.

INTRODUCTION

The biological degradation and stabilization of organic wastes by earthworms and microorganisms is termed vermicomposting, and vermicomposts are excellent plant growth media or soil amendments (Edwards, 1998). Suppression of various soil-borne diseases by traditional thermophilic composts has been reported (Chung, *et al.*, 1988). Certain types of composted pine bark suppressed *Pythium* damping-off diseases when incorporated into planting mixes (Boehm, *et al.*, 1993).

Only a few studies have investigated the suppression of soil-borne plant pathogens by vermicomposts (Szczech, et al., 1993), or disease suppression in the presence of earthworms (Stephens & Davoren, 1997; Stephens, et al., 1994). Disease suppression by composts has been attributed to the activities of competitive or antagonistic microorganisms. The main objective of our experiments was to determine the potential of vermicomposts to suppress the incidence of the plant diseases *Pythium* and *Rhizoctonia* in cucumbers and radishes in the laboratory, and *Verticillium* in strawberries in the field.

MATERIALS AND METHODS

Suppression of *Pythium* damping off in cucumber plants by substitution of vermicomposts into a greenhouse soil-less bedding plant medium (MM360)

Pythium ultimum inocula were prepared by infesting an autoclaved (1h, 121 °C) light peat mix with *Pythium.* The potting mixtures were prepared by substituting 0, 10, 20 and 40% food waste vermicompost (Oregon Soil Corporation, Oregon City, OR) into a soil-less growth medium Metro Mix 360 (MM360) (Scotts Co., Marysville, OH), with half of all treatments sterilized by autoclaving. All treatments were inoculated with 0.5 g/litre (1:4000 dilution) *Pythium* inoculum. For all treatments, involving 0, 10, 20 and 40% vermicompost substituted into sterilized or unsterilized media, eight cucumber seeds were planted in each of 5 replicate, 15-cm diameter pots. The seedlings were kept in a growth chamber at 20 °C with 16-hour illumination, and watered daily. Ten days after germination, they were harvested and rated for disease severity, according to the following scale: 1, symptomless; 2, emerged but wilted; 3, post-emergent damping-off; and 4, pre-emergent damping-off. Completely randomized designs were used, and one way ANOVA was used with Minitab statistical software (Minitab Inc., State College, PA). Separations of means were based on the least significant differences ($P<0.05$).

Suppression of *Rhizoctonia* root rot in radish seedlings by substitution of vermicomposts into a greenhouse soil-less bedding plant medium (MM360)

Rhizoctonia solani inocula, prepared using the following method: 500 ml soil and 50 g finely-chopped potatoes, in 35 ml water, were placed in a 500 ml flask. The mixtures were autoclaved twice over 2 days, for 1 hour. After cooling, the soil/potato mixture was inoculated with agar plugs of *Rhizoctonia* and incubated for 2 weeks. It was dried overnight at room temperature and sieved through 2-mm and 1-mm sieves; the inoculum collected in between the 2-mm and 1-mm sieves was saved and the rest discarded. The potting media were prepared by substituting 0, 10, 20 and 40% of either autoclaved or unsterilized cow manure-based vermicompost into sterilized or unsterilized MM360. All treatments, except the controls, were inoculated with 0.5 g/litre (1:2000 dilution) *Rhizoctonia* inoculum, and 35 g of slow release fertilizer (14-14-14) was added per 2.2 litre of planting medium. For all treatments, 32 radish seeds were planted in each of 5 replicate, 10-cm diameter pots. The seedlings were kept in a growth chamber at 25°C under continuous light. After 7 days, the seedlings were harvested and rated for disease severity, according to the following scale: 1, symptomless; 2, small lesion on the stem; 3, large lesion on the stem; 4, post-emergent damping-off; and 5, pre-emergent damping-off. Incidence of pre-emergent damping off was calculated by subtracting the numbers of seedlings that emerged from the numbers that emerged in the non-inoculated controls (both sterilized and unsterilized MM360). Completely randomized designs were used, and one way ANOVA was performed using SAS software (SAS Institute, Cary, NC). Separations of means were based on least significant differences ($P<0.05$).

In a second experiment, the same procedure was used, except that the concentrations of vermicompost used were: an uninoculated control, and 0, 20, 40, 60, 80 and 100% substitutions of vermicompost, which was not sterilized, into equivalent amounts of either sterilized or unsterilized MM360. For a third trial, the concentration of the inoculum added was increased to 1.5 g/litre (1:667 dilution), and the inoculum was incubated for 3 weeks.

The vermicompost substitutions used in a third trial were 0, 10, 20, 40 and 70% of unsterilized cattle-based vermicompost substituted into 100, 90, 80 60 and 30% of unsterilized MM360.

Suppression of *Verticillium* wilt in strawberry plants in vermicompost-amended field soils

Six-week old strawberry seedlings var. 'Chandler' were grown in soils under high plastic tunnel hoop house structures measuring 9.14 x 14.6 x 3.6 m. Twenty-four plants were transplanted into each bed with 38 cm between plants with three rows spaced 38 cm between rows. Food and paper waste vermicomposts were surface-applied at 5.0 and 10.0 t/ha. Plastic mulch and drip irrigation systems were set-up over the raised beds after vermicompost and fertilizer applications. Disease severity was rated using the proportion of the total leaves and stems that showed *Verticillium* wilt symptoms. Treatments were replicated four times in a completely randomized design and differences between means were separated using least significant differences ($P<0.05$).

RESULTS

Suppression of *Pythium* damping off in cucumber plants by substitution of vermicomposts into a greenhouse soil-less bedding plant medium (MM360)

Substitution of equal amounts of unsterilized vermicompost into sterilized MM360 increased *Pythium* suppression in cucumber seedlings significantly at all substitution rates (Figure 1). Substitution of sterilized vermicompost into sterilized MM360 also increased *Pythium* suppression in cucumber seedlings significantly, but to a lesser degree, and only at 20% and 40% substitutions.

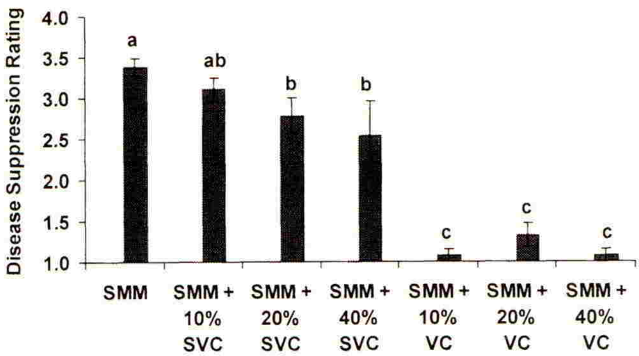

Figure 1. *Pythium* symptom suppression in cucumber seedlings planted in a soil-less medium (MM360) substituted with vermicompost, inoculated with 1:4000 dilution *Pythium* (mean ± standard error). SMM is sterilized MM360, VC is vermicompost and SVC is sterilized vermicompost. The disease scale is rated 1(symptomless) to 5 (severe). Columns followed by the same letter do not differ significantly ($P<0.05$).

Suppression of *Rhizoctonia* in radish seedlings by vermicompost-substituted greenhouse growth medium

Substituting unsterilized vermicomposts into sterilized MM360 increased disease suppression significantly at the rate of 40% vermicompost by volume (Figure 2). Substitution of sterilized vermicompost substituted into MM360 did not suppress *Rhizoctonia* significantly. In the second trial, vermicompost substituted into sterilized MM360 at concentrations of 40% and higher increased *Rhizoctonia* suppression significantly, compared with that in sterilized MM360 alone (Figure 3). In the third trial, when the inoculum concentration was increased threefold and incubated, unsterilized vermicompost substituted into unsterilized MM360 resulted in significantly increased *Rhizoctonia* suppression compared with that in unsterilized MM360 alone at 10%, 20%, 40% and 70% substitutions (Figure 4).

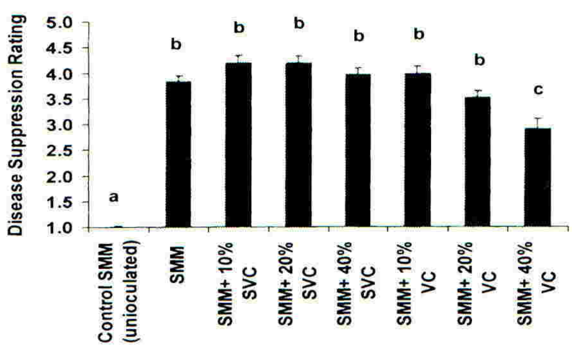

Figure 2. *Rhizoctonia* symptom suppression in radish seedlings planted in a soil-less medium (MM360) substituted with vermicompost, inoculated with 1:2000 dilution *Rhizoctonia* (mean ± standard error). SMM is sterilized MM360, VC is vermicompost and SVC is sterilized vermicompost. The disease scale is rated 1 (symptomless) to 5 (severe). Columns followed by the same letter do not differ significantly (P<0.05).

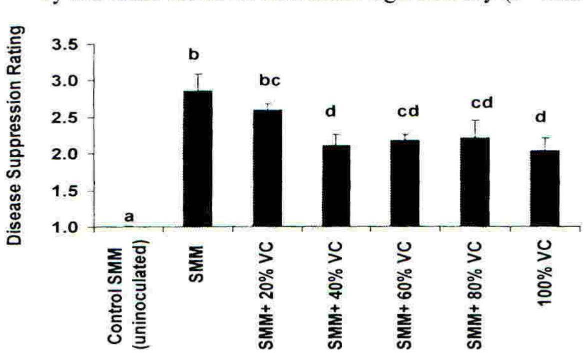

Figure 3. *Rhizoctonia* symptom suppression in radish seedlings planted in a soil-less medium (MM360) substituted with vermicompost, inoculated with 1:2000 dilution *Rhizoctonia* (mean ± standard error). SMM is sterilized MM360 and VC is vermicompost. The disease scale is rated 1 (symptomless) to 5 (severe). Columns followed by the same letter do not differ significantly (P<0.05).

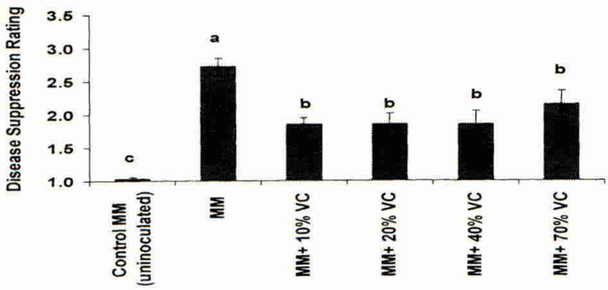

Figure 4. *Rhizoctonia* symptom suppression in radish seedlings planted in a soil-less medium (MM360) substituted with vermicompost, inoculated with 1:667 dilution *Rhizoctonia* (mean ± standard error). MM is unsterilized MM360 and VC is vermicompost. The disease scale is rated 1 (symptomless) to 5 (severe). Columns followed by the same letter do not differ significantly ($P<0.05$).

Suppression of *Verticillium* wilt in strawberry plants in vermicompost-amended field soils

Surface applications of 5 t/ha food waste, 10 t/ha food waste and 5 t/ha paper waste vermicomposts suppressed significantly the symptoms of *Verticillium* in field strawberries compared with the use of the inorganic fertilizer (Figure 5).

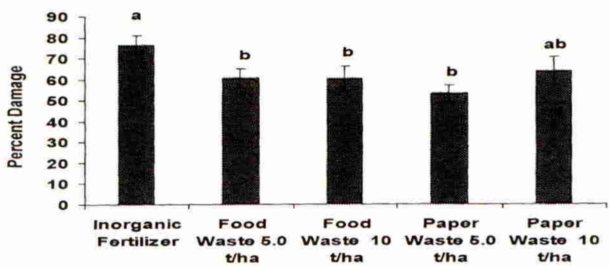

Figure 5. *Verticillium* wilt symptom suppression in strawberry field crops amended with topical applications of vermicompost (mean ± standard error). The percentage damage represents the proportion of plants per plot that were damaged by wilt. Columns followed by the same letter do not differ significantly ($P<0.05$).

DISCUSSION

Only small quantities (10% by volume), of vermicompost substituted into sterilized MM360, were required to induce *Pythium* suppression. This might be due to less aeration in the soil, leading to a greater competition between *Pythium* and beneficial microorganisms for resources, since *Pythium* is reported to be suppressed through general microbial suppression (Craft & Nelson, 1996). Unsterilized vermicompost substituted into sterilized MM360 increased *Pythium* suppression in cucumber seedlings to a significantly greater extent than sterilized vermicompost, evidence that the resistance was probably due to the high microbial activity of the vermicompost.

In the first *Rhizoctonia* trial, only the largest amount of vermicompost substituted into sterilized MM360 (40% by volume) suppressed *Rhizoctonia. Trichoderma sp.* has been identified as a biocontrol agent for *Rhizoctonia*, and might have been responsible for the suppression. The second trial indicated that increasing the vermicompost substitutions above 40% in sterilized MM360 did not increase the amount of disease suppression significantly (Figure 3). The decreases in disease suppression when sterilized vermicomposts were substituted into MM360 showed clearly the negative effects of vermicompost sterilization on its potential for disease suppression.

The use of vermicomposts suppressed significantly the diseases *Pythium* and *Rhizoctonia* in the laboratory and *Verticillium* in the field. However, the mechanisms of suppression cannot be identified in these exploratory experiments. It is well-established that traditional thermophilic composts can suppress the incidence of a number of plant diseases, probably by competition with or antagonism to non-pathogenic microorganisms (Craft & Nelson, 1996). There is good evidence that earthworms promote microbial activity and diversity in organic wastes to levels even greater than those in thermophilic composts (Edwards, 1998). Hence, there seems to be an even greater potential for suppression of plant disease by vermicomposts than by composts, probably due to stimulatory effects on soil microbial activity (thereby encouraging competing microorganisms). This conclusion seems to be supported by the results of our experiments.

REFERENCES

Boehm M J; Madden L V; Hoitink H A J (1993). Effect of organic matter decomposition level on bacterial species diversity and composition in relationship to *Pythium* damping-off severity. *Applied and Environmental Microbiology* **59**, 4171-4179.

Chung Y R; Hoitink H A J; Lipps P E (1988). Interactions between organic-matter decomposition level and soilborne disease severity. *Agriculture, Ecosystems and Environment* **24**, 183-193.

Craft C M; Nelson E B (1996). Microbial properties of composts that suppress damping-off and root rot of creeping bentgrass caused by *Pythium graminicola*. *Applied and Environmental Microbiology* **62**(5), 1550-1557.

Edwards C A (1998). The use of earthworms in processing organic wastes into plant growth media and animal feed protein. In: *Earthworm Ecology,* ed C A Edwards, pp. 327-354. CRC Press: Boca Raton, Florida.

Stephens P M; Davoren C W (1997). Influence of the earthworms *Aporrectodea trapezoides* and *A. Rosea* on the disease severity of *Rhizoctonia solani* on subterreanean clover and ryegrass. *Soil Biology and Biochemistry* **29**(3/4), 511-516.

Stephens P M; Davoren C W; Ryder M H; Doube B M; Correll R L (1994). Field evidence for reduced severity of *Rhizoctonia* bare-patch disease of wheat, due to the presence of the earthworms *Aporrectodea rosea* and *Aporrectodea trapezoides*. *Soil Biology and Biochemistry* **26**(11), 1495-1500.

Szczech M; Rondomanski W; Brzeski M W; Smolinska U; Kotowski J (1993). Suppressive effect of a commercial earthworm compost on some root infecting pathogens of cabbage and tomato. *Biological Agriculture and Horticulture* **10**(1), 47-52.

The effect of organic amendments on stem canker and black scurf (*Rhizoctonia solani*) of potatoes

G Davies, O Woolley
IOR-HDRA, Ryton Organic Gardens, Coventry, CV8 3LG, UK
Email:gdavies@hdra.co.uk

P Gladders
ADAS Boxworth, Boxworth, Cambridge CB3 8NN, UK

M Wolfe
Elm Farm Research Centre, Hamstead Marshall, Newbury, Berks RG20 0HR, UK

R Haward
Soil Association, Bristol House, 40-56 Victoria St., Bristol BS1 6BY, UK

ABSTRACT

Stem canker and black scurf are diseases of potato caused by *Rhizoctonia solani*, which are increasingly important in organic systems as high quality produce is required to meet market requirements. Soil amendments have potential to suppress soil-borne diseases, but are not widely exploited in commercial production. This paper reports an evaluation of a range of organic amendments on stem canker and black scurf. Treatments were used at realistic commercial rates and timings in a naturally-infested soil in a glasshouse experiment. Chitin, cabbage, vetch and rye amendments reduced the severity of black scurf, whilst seaweed and manure increased its severity. No treatments reduced the length of canker lesions. Straw reduced vigour and tuber number. Care should be taken in choosing amendments and cropping systems in organic disease management programmes as some have potential to aggravate rather than suppress soil-borne pathogens.

INTRODUCTION

Organic soil amendments and conditioners have traditionally been used by organic growers as part of soil fertility programmes. It is also recognised that they may also have potential against a variety of disease problems in the field (Lumsden *et al.*, 1983; Lazarovits *et al.*, 2001) although few are being used by commercial growers as components of disease management strategies. Black scurf and stem canker are fungal diseases of potato caused by *Rhizoctonia solani*, which are increasingly important in markets demanding high quality produce from both organic and conventional systems. It causes problems with crop establishment, due to canker, and marketing, due to black sclerotia on the tubers. The disease is more prevalent in dry, cold soils and reduced at high (alkaline) pH values.

Light, temperature, pH and soil moisture, acting alone, or in combination, all have considerable effects on *Rhizoctonia* activity (Brenchley & Wilcox, 1979). Conditions that slow plant growth or increase exposure of shoots and stolons to the pathogen in the soil are likely to increase stem canker severity; potato cyst nematode (*Globodera* spp.) attack may also increase canker severity (Back *et al.*, 2000). In contrast, there is some evidence that stimulating soil biological activity, especially populations of mycophagous soil mesofauna, can contribute to a reduction in disease severity (Scholte & Lootsma, 1998).

Organic amendments have the capability to alter both soil biological and physical factors and so have the potential to affect the incidence of *Rhizoctonia* disease on potatoes. Farmyard manures (FYM) and green manure crops (white mustard, forage rape and oats) have been shown to reduce severity of canker, especially FYM combined with white mustard and oats as a cover crop (Scholte & Lootsma, 1998). A rye-sand-soil medium has also been shown to decrease stem and stolon cankering, possibly due to the stimulation of indigenous antagonists (Anon, 1983). This paper reports the results of an experiment to assess the ability of several commonly used organic soil amendments or conditioners to suppress the occurrence and severity of *Rhizoctonia* symptoms on potato.

MATERIALS AND METHODS

A loamy sand soil was obtained, in autumn 2000, from an organically certified HDRA reference farm. The soil was taken from a field where a potato crop had shown severe black scurf problems in 2000. Organic amendments were added to infected soil at realistic farm application rates (calculated for pot area used) and timings to simulate actual organic agricultural practice (Table 1). Crop residues, green manures, FYM and other amendments were obtained from established organic holdings. Commercial products were applied according to the manufacturers recommendations. Soil pH was measured at the beginning and end of the trial (see Table 1). The amount of nitrogen (N) added with each treatment (gN/m^3 of soil) was calculated from secondary data obtained on N content of amendments (see Table 1).

Table 1. Application rate and timing of organic amendments used in trial

Amendment	Application Rate (g/m^2)	Frequency	Soil pH at end of expt[e]	N applied (g/m^3)
Vetch	1250	1[b]	7.81	76
Rye	3000	1[b]	8.01	132
Clover	1250	1[b]	7.82	76
Cabbage	2000	1[b]	8.16	124
Straw	2500	1[b]	8.06	246
Compost	3500	1[b]	7.89	294
Seaweed Meal	140	2[c]	7.95	45
Chitin	800	2[c]	8.83	342
Neem	10	2[c]	8.09	Effectively 0
Manure	2500	1[b]	7.95	14
Composted Manure	3500	1[b]	8.16	258
Comfrey	12[a]	4[d]	8.05	Effectively 0
Seaweed Extract	3[a]	4[d]	7.75	Effectively 0

[a] ml per m^2 [b]4 weeks before sowing [c]4 weeks before and at sowing [d] Weekly until sowing [e]pH with no amendment = 7.88

In order to evaluate the effect of the amendments a plant bioassay was carried out using commercial seed potatoes (var Forty Fold from Specialist Potatoes Ltd., Fife) in 254 mm pots containing the amended soil. Six potatoes were planted at 15 cm depth in the pots four weeks after amendment and grown at 20°C under glasshouse conditions. The trial design was a randomised complete block with six replicates. The potatoes were assessed for disease symptoms and vigour (1= very vigorous to 9= very poor) at 50% emergence. Disease was recorded by counting the total number of shoots, number of shoots with severe canker (dieback /dead tips) and the number of shoots with canker symptoms. The length of canker lesions was measured twelve weeks after emergence. Shoots were cut at soil level (to stimulate development of black scurf on daughter tubers) and shoot dry weight was measured. Potatoes were dug up and percentage tuber area with black scurf assessed sixteen weeks after emergence. The number of tubers and total tuber weight was also recorded.

The results of the trial were analysed using standard ANOVA procedures for complete block designs using the SYSTAT 8.0 statistical package. Where the ANOVA indicated statistical differences between treatments, specific differences were then identified with a pair-wise comparison test using the Tukey method.

RESULTS

Significant differences were observed between treatments in the percentage of tuber area covered with black scurf (Table 2). Chitin, cabbage, vetch and rye treatments gave good reductions (>67%) in black scurf, whilst manure and seaweed increased its severity. However, no significant differences were observed in the percentage of shoots with die-back or the total percentage of shoots with stem canker symptoms although most amendments showed higher disease indices than the untreated soil in this respect (Table 2). Small, but significant increases in the length of canker lesions were observed in composted manure and neem treatments.

There were differences between treatments in the total number of shoots and in shoot vigour (Table 2). Rye increased vigour, whilst seaweed extract reduced shoot vigour. There was a positive correlation between vigour and number of shoots ($r= 0.87$, $p<0.01$). The more vigorous plants also tended to have less shoot dieback ($r= 0.58$, $0.01<p<0.05$), less total canker ($r=0.52$, $0.05<p<0.10$) and less black scurf on tubers ($r=0.57$, $0.01<p<0.05$).

Several treatments increased the dry weight of harvested shoots after 12 weeks, but straw decreased shoot dry weight and tuber number (Table 2). Shoot dry weight was influenced by the amount of available nitrogen (N) added in the amendment ($r= 0.94$, $p<0.01$) when straw, compost and composted manure were omitted from the analysis. Although straw, compost and composted manure contain large amounts of N this was apparently not available for plants to use during this short term experiment.

There did not appear to be any relationship between pH and disease or plant vigour indices. Only chitin produced a large change in soil pH.

Table 2. Effects of organic amendments on vigour, growth and disease.

Amendment	Shoot vigour (1-9)	No shoots /pot	% shoots dead tips	% canke r /pot	Length canker lesion (cm)	Dry weight shoots/pot (g)	No. tubers /pot	% tuber area with black scurf
Chitin	3.6	17.3	16.8	44.4	1.7	14.4	12.5	0.15[b] (0.4)
Cabbage	5.3	15.5	29.6	69.8	1.8	9.6	12.3	0.35 (1.2)
Vetch	5.1	16.7	37.7	62.8	2.8	10.7	10.2	0.39 (1.5)
Rye	3.2	18.5	10.6	37.8	1.5	10.0	16.8	0.42 (1.6)
Composted Manure	5.8	16.5	23.6	63.4	3.1	7.2	12.5	0.63 (3.3)
Straw	7.2	11.8	21.8	41.2	1.1	4.4	6.5	0.77 (4.9)
Clover	4.7	18.8	25.1	44.6	1.8	7.9	17.7	0.78 (5.0)
Seaweed Extract	6.8	13.3	39.2	68.9	2.4	6.4	11.2	0.83 (5.8)
Comfrey	6.2	14.0	18.8	61.3	2.4	6.6	13.2	0.86 (6.2)
Compost	4.3	16.7	11.5	45.4	2.3	7.4	14.7	0.87 (6.4)
Neem	6.2	16.2	32.6	69.0	3.9	6.1	16.8	0.92 (7.2)
Manure	6.5	13.5	32.9	65.3	2.0	6.9	13.0	0.97 (8.3)
Seaweed Meal	6.0	14.5	24.3	52.1	1.9	6.4	16.2	1.05 (10.2)
Untreated	5.1	15.7	18.3	39.7	1.6	7.3	12.7	0.77 (4.9)
SED (71 df)	0.82	1.94	10.29	15.68	0.69	0.78	2.71	0.21 (-)
sig	***[a]	*	ns	ns	*	***	**	**

[a] *** $0.001>p$ ** $0.001<p<0.01$ * $0.01<p<0.05$ ns not significant

[b] data transformed (log(x+1)) for ANOVA, original treatment means shown in brackets

DISCUSSION

This experiment showed that the addition of organic amendments can produce useful reductions in black scurf on tubers, but some treatments could have adverse effects on both stem canker and black scurf. These results support previous observations that organic amendments are capable of both suppressing (e.g. potato scab (*Streptomyces scabies*)) and aggravating (e.g. *Fusarium solani* f. sp. *phaseoli* on beans) pathogens depending on the circumstances (Lumsden *et al.*, 1983). In the case of potato stem canker, Scholte & Lootsma (1998) found that disease severity was only slightly reduced by farmyard manure and mustard, but significantly so by the use of oats as a green manure. They suggested as a hypothesis that stimulating populations of mycophagous soil mesofauna could contribute to a reduction in canker disease severity in potato.

Indeed, detailed explanations as to the effects observed in the trial reside in the complex soil – plant – pathogen interactions that are occurring even in such an apparently simple experiment. These include direct effects on the disease (through toxic effects on the pathogen, alteration of soil properties affecting pathogen activity, stimulation of antagonistic organisms) and indirect effects on plant nutrition and plant resistance (Lazarovits *et al.*, 2001). Some of these factors are discussed in more detail below.

Chitin, cabbage, rye and vetch treatments gave reductions in black scurf over the other treatments. The mechanisms of action of these amendments probably differ. Chitin, for example, would be expected to stimulate chitin-digesting flora in the soil (Mitchell, 1963), which could attack the mycelium of *R. solani* and thus reduce disease severity. There may also have been effects from the higher soil pH after chitin treatment. Grazing rye and cabbage are both known for releasing pathogen suppressing substances such as phenolic compounds and isothiocyanates (Gardiner *et al.*, 1999) as they decompose and this could have led to the low levels of black scurf observed with these treatments. The suppressive effects of rye on black scurf and its known effects on other pathogenic organisms (e.g. *Pythium* spp.) (Rothrock & Hargrove, 1988) suggests that it is a promising treatment for inclusion in larger scale studies.

In contrast, neem, manure and seaweed extract tended to exacerbate black scurf. Manure and seaweed could provide nutrients favouring the saprophytic development of the pathogen, whilst neem, a known broad-spectrum fungicide and insecticide (Kamalakannan *et al.*, 2001), could reduce microbial competition for the pathogen in the amended soil.

As a confounding factor, plant vigour and dry shoot weight generally correlated well with the amount of nitrogen (N) that was added in the amendments except in the case of composted or straw amendments where the N was considered to be unavailable for immediate plant use. The more vigorous plants tended to have more and heavier shoots, but also less disease. Susceptibility to disease can often depend on the nutrient status of a plant, with well-nourished plants better able to resist disease, and this could account for some of the effects seen in the trial apart from the direct effects of amendments on the disease. pH in itself did not seem to obviously affect plant vigour or growth in these trials though changes were small and none created acid conditions.

The trial results indicate that amendments might play an important role in *Rhizoctonia* (stem canker and black scurf) management in potato. The addition of organic amendments such as manures or composts and use of fertility building crops is a vital part of organic systems. There is interest in using composts for disease suppression and benefits have been shown in small-scale experiments against clubroot (*Plasmodiophora brassicae*) (Pitt *et al.*, 1997). However, it is also possible that such treatments crops could also assist the survival of soil-borne pathogens. It would appear that care is required to establish that such treatments produce a net benefit and do not solve one problem only to create others. To enhance understanding of the mechanisms of action of organic amendments in this plant-pathogen system more detailed microbiological analyses could be undertaken which might offer long-term benefits.

Existing organic growers with black scurf problems have to consider the full range of their management options. Apart from the use of organic amendments, the rotation of susceptible root crops might be extended, and soil tests to quantify inoculum of *R. solani* could be used to guide field selection. Agronomic factors such as delaying planting and use of chitted seed would reduce the impact of stem canker pre-emergence. Black scurf increases rapidly after haulm killing and haulm pulling might be a useful technique to adopt (Read, 1996). Prompt harvesting alone may also provide benefits for quality. In future, promising biological control agents such as *Verticillium biguttatum* and *Gliocladium virens* may become available for use in potatoes.

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REFERENCES

Anon. (1983). Control of *Rhizoctonia solani* in potato plants and tubers. *Report of Long Ashton Research Station 1981*, p100-102.

Back M A; Jenkinson P; Haydock P P J (2000). The interaction between potato cyst nematodes and *Rhizoctonia solani* diseases in potatoes. *Proceedings of the BCPC Conference – Pests and Diseases 2000* **1**, 503-506.

Brenchley G H; Wilcox H J (1979). *Potato Diseases*. MAFF, London. 105pp.

Gardiner J B; Morra M J; Eberlein C V; Brown PD; Borek V (1999): Allelochemicals released in soil following incorporation of rapeseed (*Brassica napus*) green manures. *Journal Agricultural Food Chemistry* **47**, 3837-3842.

Lazarovits G; Tenuta M; Conn KL (2001). Organic amendments as a disease control strategy for soilborne diseases of high-value agricultural crops. *Australasian Plant Pathology* **30**, 111-117.

Lumsden R D; Lewis J A; Papavizas G C (1983). Effect of organic amendments on soilborne plant diseases and pathogen antagonists. In: *Environmentally Sound Agriculture,* ed. W Lockeritz, p 51-70. Praegar: New York.

Mitchell R (1963). Addition of fungal cell-wall components to soil for biological disease control. *Phytopathology* **53**, 1068-1071.

Pitt D; Tilston E L; Groenhof A C (1997). Recycled organic materials (ROM) in the control of plant diseases. In: *Proceedings of the International Symposium on Composting and Use of Composted Materials for Horticulture* ed. Szmidt R A K. *Acta Horticulturae* **469**, 383-404

Read P J (1996). Effect of double cropping on the incidence of disease caused by Rhizoctonia solani in potatoes. *Aspects of Applied Biology* **47**, 445-448.

Rothrock C S; Hargrove W L (1988). Influence of legume cover crops and conservation tillage on soil populations of selected fungal genera. *Canadian Journal of Microbiology* **34**, 201-206.

Scholte K; Lootsma M (1998). Effect of farmyard manure and green manure crops on populations of mycophagous soil fauna and *Rhizoctonia* stem canker of potato. *Pedobiologia* **42 (3)**, 223-231.