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Title: ***Effectiveness of compost extracts as disease suppressants in fresh market crops in British Columbia***

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Introduction

One of the major challenges facing organic producers is disease management. The losses in vegetable production due to disease can be significant and, in some cases, can devastate entire crops. Cultural methods of disease control are commonly used on organic farms. The application of organic chemicals for disease control is often a last resort and can be regulated by organic certification bodies while biological control is still not readily available. The use of compost extracts then, presents a simple, inexpensive and potentially effective method to supplement the on-farm disease management program.

The effectiveness of using composts for disease control, particularly against fungal pathogens, has been studied extensively (Weltzein, 1991;Grobe, 1997; reviewed in Hoitink et al., 1997). Composts of various kinds have been used to reduce the incidence of *Pythium* and *Rhizoctonia* in a variety of vegetables and fruits (Gottschall et al., 1987; Weltzien and Ketterer, 1986). These results have led to further work using filtered extracts of composts. In some cases, the compost extracts were even more effective in controlling disease than conventional pesticides (Weltzien et al., 1987). Stindt and Weltzien (1988) at the University of Bonn achieved effective control *of Botrytis cinerea* in strawberries as well as blight in potatoes. Similarly, powdery mildew and root rot were significantly reduced in peas and beets in other trials in Germany (Thom and Moller, 1988).

During the 1999 growing season, a trial on compost extracts was undertaken to determine their effectiveness in reducing disease in fresh market crops. From the results of those trials, future studies on compost extracts were planned and carried out for the subsequent field season. We had found extracts prepared from cattle compost to be the most effective and that strawberries and broccoli showed the most response to treatment with the extracts. Results from the trials on application time of the extracts were not as clear and so were repeated in 2000. We also added other variables related to compost extract preparation; aerobic vs. anaerobic preparation, the degree of dilution and the age of the extract prior to application. These all appear to be factors that can determine the efficacy of a compost extract and can also vary with the type of crop. This report summarizes the results of the 2000 season and tries to indicate trends found over the past 2 years of field trials conducted at a certified organic farm in the Southern Interior of British Columbia.

Project Objectives:

1. To determine the effects of aerobically and anaerobically prepared cattle compost extract on yield and disease reduction in strawberries and broccoli.
2. To compare the effects of different compost extract application times (greenhouse, field or both) on yield and disease reduction in strawberries and broccoli.
3. To determine if the age of the compost extract (fresh or aged) has an effect on the yield and disease reduction in broccoli.

Experimental Methods:

General description of study site:

The trials took place at Wildflight Farm located in the floodplain of the Shuswap River near Mara in the North Okanagan region of British Columbia. The annual rainfall of the area is approximately 1300 mm with warm, humid summers. The plots were established on level or slightly undulating land with a soil of a clay loam texture. This particular farm provides produce for the fresh market and a CSA, and thus grows a wide variety of vegetables including brassicas, tomatoes, potatoes, salad greens, onions, garlic, leeks, strawberries, cucurbits, carrots and beets.

Crop planting and other details

Strawberries (Brunswick variety) were established in the spring of 1999 at recommended densities. Treatment plots were superimposed onto the existing strawberry fields and were ribboned off to separate them from the rest of the field. Broccoli (Pakman variety) was seeded into trays with the following soilless mix: 4:4:1 of chicken manure compost, peat and vermiculite, respectively. Some dolomitic lime was also added to adjust the pH to 7. Seedlings were raised in the greenhouse until ready for transplanting and were irrigated with overhead watering.

Compost extract preparation:
Cattle compost from Greenleaf (Olds, AB) was used for the extractions (see analysis in Results section). The composts were actively turned for the first month and then only once a month for the next 3 months, then cured for another 6 months. Compost tea was prepared according to the following methods based on research with aerobic and anaerobic teas:

Anaerobic compost extract preparation
1. A method of compost extraction proposed by researchers at the Wood's Hole Laboratory was used (Brinton, 1995). This resulted in an 8:1 water to compost dilution. Water was added to the compost and the mixture was stirred for about 10 minutes every day of the week long extraction period. Subsequently, the extract was filtered through several cheesecloths, and then stored outside away from sunlight until use on crops. A double strength, less dilute solution was also prepared with a 4:1 water to compost ratio and was prepared in the same manner.

Aerobic compost extract preparation
1. Aerobic compost extract was prepared by bubbling oxygen (with an aquarium pump) through a mixture of either 8:1 water to compost and 4:1 water to compost for a period of 1 week. After the extraction period, the compost was filtered through cheesecloths and aerated until use on crops.

Application details
The compost extract was applied with a backpack sprayer that was rinsed thoroughly with water before and after each type of extract. Broccoli seedlings were sprayed with a small spray bottle while still in the greenhouse. Crops were sprayed as long as weather allowed (i.e. extended wet periods). Sprays were applied at a rate that ensured coverage of all foliage. Approximate application rates are listed below:

1. Strawberries
   →sprayed twice a week at 1.3 litres/m^2 (0.03 gallons/$ft.^2$)

2. Broccoli
   →in the greenhouse, about 50 ml (2 ounces) was applied to 1 seedling tray (90 plants)
   →in the field sprayed twice a week at approximately 1 litre/m^2 (0.02 gallons/$ft.^2$)

Plot layout and treatments:
All trials were on the same soil, a clay loam and were generally on level ground. Strawberries and broccoli trials were laid out in a completely randomized design with 4 replications. The following treatments were imposed on existing plants in the field and assigned to broccoli seedling in the greenhouse.

1. Strawberry trial
   a. Aerobic compost extract, single strength (8:1 water to compost dilution)
   b. Aerobic compost extract, double strength (4:1 water to compost dilution)
   c. Anaerobic compost extract, single strength (8:1 water to compost dilution)
   d. Anaerobic compost extract, double strength (4:1 water to compost dilution)
   e. Water only
   f. Control (no applications only regular irrigation)

2. Broccoli trials

A. Aerobic compost extract (single strength) – application time trial
   i) Field application only
   ii) Greenhouse application only
   iii) Greenhouse and field application
   iv) Water application - field only
   v) Water application – greenhouse only
   vi) Water application – greenhouse and field
   vii) Control

B. Anaerobic compost extract (single strength) – application time trial
   i) Field application only
   ii) Greenhouse application only
   iii) Greenhouse and field application
   iv) Water application - field only
   v) Water application – greenhouse only
   vi) Water application – greenhouse and field
   vii) Control

C. Aerobic compost extract (double strength) – extract age trial
   i) Fresh compost extract application (after preparation)
   ii) Aged compost extract application
   iii) Water
   iv) Control

Measurements

Strawberries

The number and weight of ripe and uninfected, marketable strawberries were taken every two to three days for the length of the harvest (approximately 1 month, from June 26, 2000 to July 12, 2000). A scale of the incidence of *Botrytis cinerea* on the surface of the berries was used: 0=no infection, 1= 1-5% berry surface affected, 2= 6-15% berry surface affected, 3= 16-50% berry surface affected and 4 = 51-95% berry surface affected. This scale is similar to those used by other researchers investigating *B.cinerea* on strawberries (Elad and Shtienberg, 1994; Archbold et al., 1997).

Broccoli

Broccoli was harvested when heads were of marketable size between October 3, 2000 to October 27, 2000. Heads were weighed and the head diameter was measured. The incidence of head rot (*Rhizoctonia solani*) was measured using the following scale: 0=no disease, 1= 1% surface area affected, 2= 10% of surface area affected, 3=30% of surface area affected, 4=60% of surface area affected and 5=100% of surface area affected. (Canaday, 1992).

Lab analyses

Samples of compost and compost extracts were sent to NorWest Labs in Edmonton and Lethbridge, Alberta, for nutrient and microbiological analyses. At harvest, samples of sprayed berries and broccoli were sent to the lab as well for microbiological analyses. Results are given in Tables 1 and 2 below.

Data analyses
All data was analyzed for normality and heterogeneity of variance prior to an ANOVA. Data was analyzed as a two-way ANOVA with the first factor being the application of compost extract or not and the second representing the various factors (either application time, compost tea strength or age). Significantly different means were separated using Tukey's test. All statistical analyses was done using SAS.

Results
Compost and compost tea analysis
The analyses yielded few surprising results. Both cattle manure compost and its extract had higher fecal coliform counts, yet these were still low enough to fall within acceptable limits and were not detected in the crops tested.

Table 1. Chemical characteristics of compost tea

Compost tea	*pH*	*Nitrate and nitrite – N (mg/L)*	*Calcium (mg/L)*	*Magnesium (mg/L)*	*Potassium (mg/L)*	*Sulphate (mg/L)*	*Electrical Conductivity (dS/m)*
Aerobic (8:1)	7.75	0.332	10.0	4.61	132	15.3	0.516
Aerobic (4:1)	8.09	0.715	11.2	6.20	204	21.6	0.745
Anaerobic (8:1)	7.70	1.20	9.2	4.88	123	14.0	0.517
Anaerobic (4:1)	7.72	0.984	11.1	6.58	194	15.2	0.774

Table 2. Microbiological characteristics of compost tea and sampled crops (MPN indicates the most probable number).

	Aerobic (8:1)	*Aerobic (4:1)*	*Anaerobic (8:1)*	*Anaerobic (4:1)*	*Strawberries*	*Broccoli*
Salmonella (presence/absence)	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
Total fecal coliforms (MPN/ml)	2.3	15.0	23.0	93.0	<0.3*	15
Fecal coliforms (MPN/ml)	0.4	<0.3	1.5	0.9	<0.3	<0.3

*0.3 MPN/ml is the laboratory's detection limit.

Strawberries
Strawberry yields (averaged over the whole harvest) were similar in both years of trials (15.6 kg/ha in 1999 and 15.2 kg/ha in 2000). There was a consistent although not always statistically significant trend of higher strawberry yields with aerobically treated compost extract compared to the control and water treatments. This became a significant trend at mid-season harvest of the berries (Figure 1). We found these results to reflect what we found in the 1999 season with the cattle compost extract.

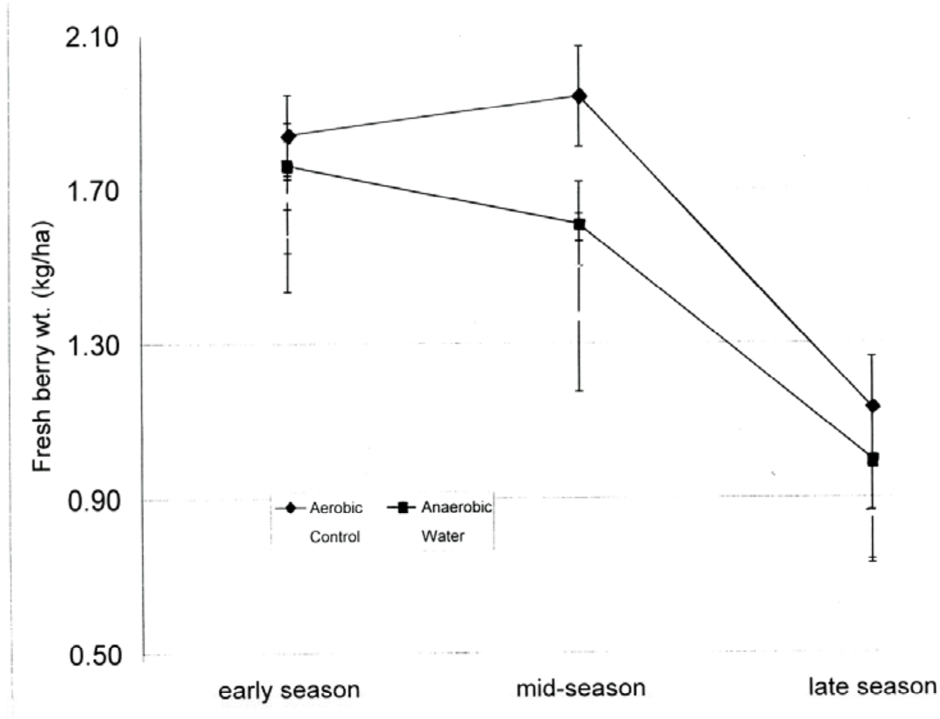

Figure 1. Strawberry yields (kg/ha) over the 2000 harvest period sprayed with aerobic and anaerobic compost extracts as well as water compared to control treatments (bars indicate standard errors of the mean).

The latter trend was also reflected in the degree to which berries were infected by *B. cinerea*. While a similar number of non-affected berries were harvested in all treatments, we found a greater incidence of severely infected berries in control and water treatments (Table 1). This trend was not evident in the previous season where there were no differences in the severity of the disease among any of the treatments.

Table 1. Disease incidence of *B. cinerea* in strawberries sprayed with compost extracts and water compared to control treatments (standard errors of the mean in brackets).

Treatment	**Disease category (% of total berries)**			
	1 (1-5% infection)	*2 (6-15% infection)*	*3 (16-50% infection)*	*4 (51-95% infection)*
Aerobic	2.50(0.32)	1.04(0.18)	0.58(0.12)	0.24(0.06)
Anaerobic	1.87(0.30)	1.03(0.22)	0.71(0.17)	0.38(0.16)
Water	2.14(0.34)	2.07(0.83)	0.94(0.22)	1.02(0.36)
Control	1.32(0.30)	1.19(0.26)	0.62(0.16)	0.74(0.35)

We also looked at the effect of compost tea dilution (an 8:1 (single) vs. 4:1 (double) dilution) on strawberry health. As we expected, simply the application of compost tea increased berry yields over the control and water treatments. This was particularly significant with the single dilution of the extract and during the middle of the harvest (Figure 2).

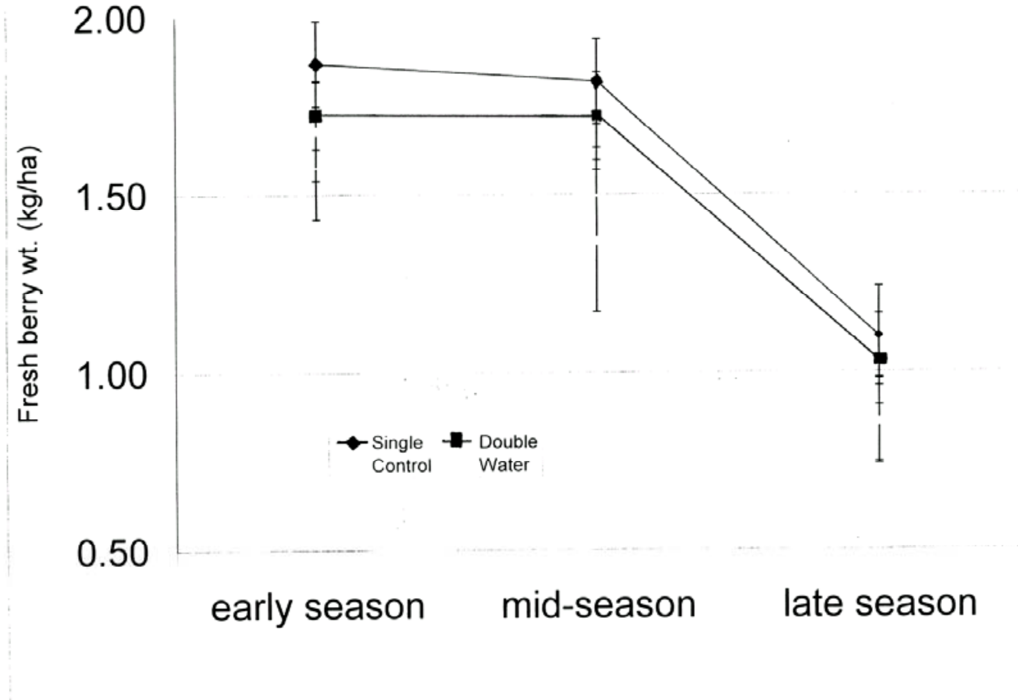

Figure 2. Strawberry yields (kg/ha) with single and double dilution compost extract over the harvest period (bars indicate standard error of the mean).

The effect of the extract dilution on the incidence of *B. cinerea* was not as clear however. The number of healthy berries and those with limited mold were similar in all treatments. Treatments sprayed with single strength compost extract, did, however, reduce the number of severely disease affected berries (Table 2).

Table 2. The effect of compost extract dilution on disease incidence of strawberries (standard errors of the mean in brackets).

Treatment	**Disease category (% of total berries)**			
	1 (1-5% infection)	*2 (6-15% infection)*	*3 (16-50% infection)*	*4 (51-95% infection)*
Single strength	1.84(0.22)	1.06(0.23)	0.82(0.18)	0.28(0.14)
Double strength	2.54(0.39)	1.02(0.17)	0.47(0.10)	0.34(0.10)
Water	2.14(0.34)	2.07(0.83)	0.94(0.22)	1.02(0.36)
Control	1.32(0.30)	1.19(0.26)	0.62(0.16)	0.74(0.35)

Broccoli
Broccoli from both the aerobic and anaerobic trials yielded similar amounts and had similar diameter heads as well as disease incidence, although the heads were generally much smaller than in the 1999 season.

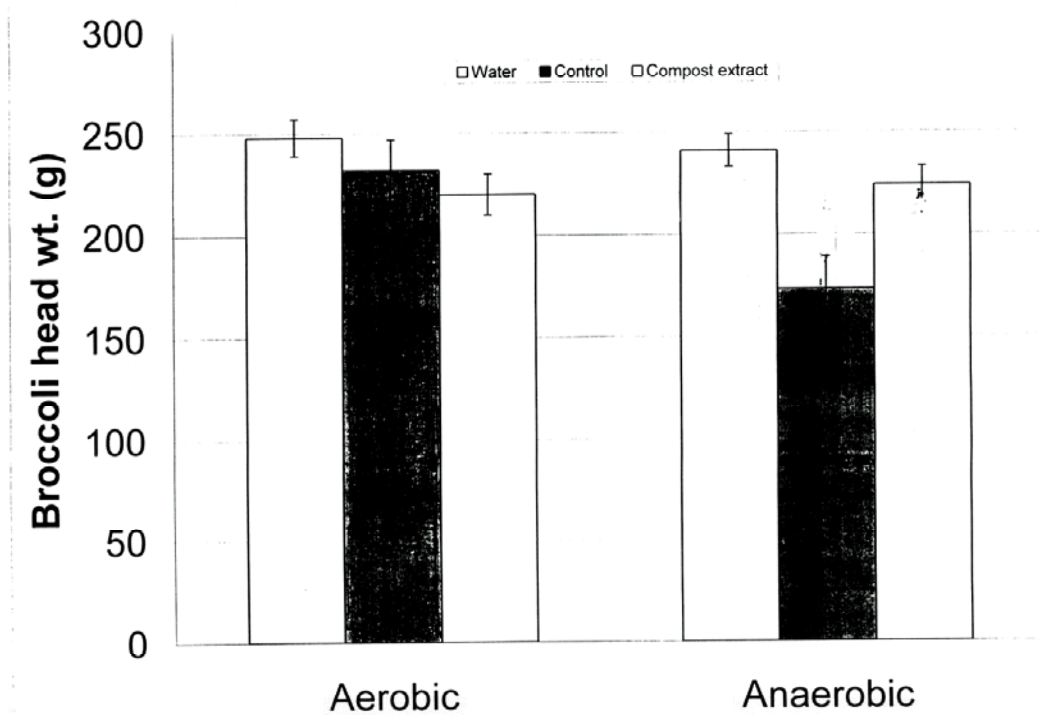

Figure 3. Broccoli head weight sprayed with aerobically and anaerobically prepared compost extract (standard error of the mean in brackets).

The effect of compost extract type and application time was analyzed over the entire broccoli harvest period and was also separated into and analyzed by 2 harvest dates, early and late. No significant differences were found with respect to compost extract type at any time (Figure 3). These results are somewhat different from the 1999 season where the application of cattle compost extract generally increased the weight of marketable heads compared to other treatments and the control. In the 2000 season, the application of water alone had the most positive effect on broccoli size and diameter. We did not find any clear differences among treatments in the incidence of head rot in either Trial#1 or Trial#2. As we observed in 1999, the control treatments had broccoli with lower average percentage of head rot (Table 3).

Table 3. Percentage of broccoli head rot as affected by compost extract and water application compared to control treatments (standard error of the mean in brackets).

	% of head rot	
	Trial #1 (aerobic)	*Trial#2(anaerobic)*
Control	1.18(0.62)	4.35(1.90)
Water	6.22(1.39)	6.33(1.40)
Compost extract	11.9(2.1)	7.21(1.47)

In both the aerobic and anaerobic compost extract trials, we found increased broccoli yields when we applied either compost extract or water only in the field or throughout the whole growing season of broccoli. This was in contrast to application at the greenhouse stage only where yields were generally lower (Table 4).

Table 4. Broccoli weight as affected by compost extract and water applied at different times in the growing season (standard error of the mean in brackets).

	Broccoli weight (grams)	
Application time	*Trial #1*	*Trial#2*
Field	240(10)	237(12)
Field + greenhouse	240(11)	254(12)
Greenhouse	216(10)	213(12)
Control	173(16)	232(15)

Significantly greater incidence of head rot was found in compost extract applications (particularly anaerobically prepared extract) at the field stage compared to all other treatments. Application of compost extract at the greenhouse stage resulted in a significantly lower incidence of head rot in both trials compared to application throughout the growing season or in the field only (F=5.63, P=0.0041 and F=5.83, P=0.0033) (Figure 4). This was also something we observed in the 1999 season.

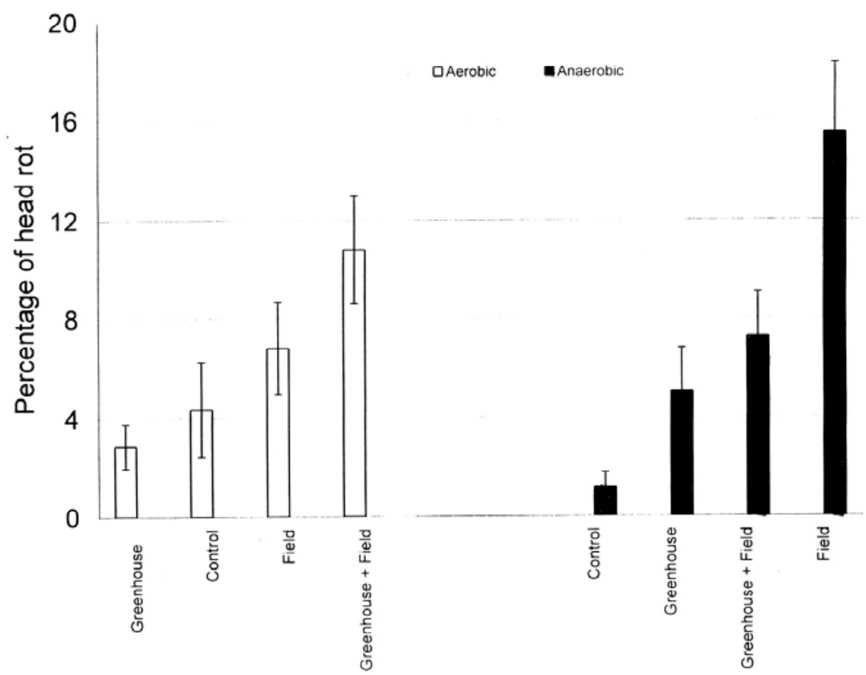

Figure 4. Percentage of head rot as affected by application time (standard error of the mean in brackets).

Trial #3 – Compost extract storage time

When we looked at the effects of compost extract storage time (prior to application), we found mixed trends. Larger, average broccoli heads were harvested with the fresh compost extract application compared to all other treatments (Table 5). However, this was also the treatment with the greatest head rot disease incidence compared to the control (F=3.14, P=0.08).

Table 5. Effects of compost extract time on broccoli head weight and head rot incidence (standard error of the mean in brackets).

	Application of fresh extract	**Application of aged extract**	**Control**
Broccoli weight	261(13)	247(16)	236(16)
Head rot (%)	11.6(2.8)	7.9(2.9)	1.9(1.1)

Discussion of results

In the 2000 trials, strawberries showed a greater response to the application of compost extract compared to broccoli and compared to other strawberry treatments. This could simply be a reflection of climatic conditions during the growing season. During the growth and harvest of strawberries, the weather was relatively dry and cool while it was particularly wet and cold during the broccoli growing season. Climatic conditions can dramatically affect the growth and development of disease in crops and so, could easily override any effects of compost extracts.

Aerobically prepared compost extract increased strawberry yield and reduced incidence of severe mold compared to anaerobically prepared extract, however the latter still outperformed both the water and control treatments. These results indicate, as other studies have, that there are advantages of aerated extract over a more ‘fermented’ one even though the application of either extract appears to have benefits over no application at all. In contrast, aerobic and anaerobic compost extracts had similar effects on broccoli weights and disease incidence.

The method of compost extraction is still an area of much discussion. Cronin and co-workers (1996), for instance, found that anaerobically prepared extracts from spent mushroom substrate were much more effective in inhibiting apple scab than aerobically treated extracts. Weltzien (1991) and Brinton (1995) also promote the anaerobic method of compost extract preparation. These researchers suggest that the likely disease-suppressive effect is a result of a metabolite produced by anaerobic microorganisms in the extract (Cronin et al., 1996). In contrast, there is also evidence that indicates that aerobically produced compost extracts are much more effective (reviewed in Anonymous, 1996). Microbiological studies have also shown that aerobic microbes dominate compost extracts (Sackenheim, 1993 in Hoitink et al., 1997). It is clearly a complicated question with possible and likely interactions with crop type, compost type, environmental conditions in addition to a multitude of other factors.

Dilution of the compost extract was investigated in the strawberry trials where we found that the single dilution (8:1) increased the yield and decreased the incidence of disease compared to other treatments. Differences between the double strength (4:1) extract and the single strength were not significant yet this trend was consistent suggesting that there may be some inhibitory effect, either chemical or biological, at the higher extract concentration. This is in contrast to other studies that have found that dilutions of extracts can reduce disease inhibition dramatically (Cronin et al., 1996; Elad and Shtienberg, 1994).

The time at which compost extract applications are most effective appears to differ depending on which variable is being measured. Continuous application and field application only favoured greater broccoli weights while applications of extract in greenhouse reduced the incidence of head rot. Since the application of water gave somewhat higher broccoli weights, it could be that moisture was more important than other factors for growth but also that there were negative chemical and microbiological factors associated with the compost extract that, when combined with poor growing conditions resulted in poorer overall growth. The fact that head rot was greater in the field correlates well with the cool, wet fall weather that was experienced and contributed to the proliferation of disease.

Compost extract incubation time also appears to be a variable in their effectiveness against disease. Urban and Trankner (1993) found that 24 hour extracts from horse and cattle manure composts effectively controlled gray mold in beans. Others, however, have only found disease suppression after an extraction period ranging from 7 to 14 days (Ketterer et al., 1992; Elad and Shtienberg, 1994). Some researchers suggest that compost extracts lose their efficacy if they are not used within about 1 week of preparation (Brinton et al, 1996). In this study, we found a trend of increased broccoli weights with fresh extracts extracts but that these extracts were also associated with higher disease incidence. It is possible that then that the mechanism responsible for contributing to growth was much reduced as the compost extract 'aged'. Yet this effect was lost in the applications of the extracts in cool, wet weather.

The effects that composts have on crops are clearly variable and could be attributed to both their chemical and biological characteristics. These, in turn, can be affected by many factors including method of preparation, extraction time, storage time and the type of crop applied on. Consistency and maturity of the compost to be extracted are yet more variables. Evaluation of compost extracts are required on specific crops and specific disease organisms over a period of several years to account for year to year variations in weather, which can significantly influence disease dynamics.

Extension activities

Several extension activities are planned to share the 1999 and 2000 results with organic growers in NOOA and in the wider Okanagan region. The preliminary results will be discussed at one or two NOOA monthly meetings prior to the 2001 growing season. Furthermore, an article on compost teas that includes the results of this study, will be submitted to a number of agricultural magazines in BC and in Canada (e.g. BC Grower, BC AgriDigest and Eco-Farm and Garden).

Acknowledgements

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References:

Anonymous. 1996. Compost teas in agriculture. BioCycle, December 1996.

Archbold, D.D., T.R. Hamilton-Kemp, M.M. Barth and B.E. Langlois. 1997. Identifying natural volatile compounds that control gray mold (*Botrytis cinerea*) during postharvest storage of strawberry, blackberry and grape. Journal of Agricultural Food and Chemistry. 45: 4032-4037.

Brinton, W.F. 1995. The control of plant pathogenic fungi by use of compost teas. Biodynamics. Jan./Feb.

Brinton, W.F., A. Trankner an M. Droffner. 1996. Investigations into liquid compost extracts. Biocycle. Nov. 1996.

Canaday, C.H. 1992. Effects of nitrogen fertilization on bacterial soft rot in two broccoli cultivars, one resistant and one susceptible to the disease. Plant Disease 76(10):989-991.

Cronin, M.J., D.S. Yohalem, R.F. Harris and J.H. Andrews. 1996. Putative mechanism and dynamics of inhibition of the apple scab pathogen *Venturia inaequalis* by compost extracts. Soil Biology and Biochemistry 28(9): 1241-1249.

Elad, Y. and D. Shtienberg. 1994. Effect of compost water extracts on grey mould (*Botrytis cinerea*). Crop Protection. 13(2):109-114.

Gottschall, R.C. et al. 1987. Verwertung von Kompost aus Bioabfall: Aufbereitung von Frisch und Fertigkomposten. In: Fricke, K et al (eds.), Zwischenbericht Forschungsprojeckt: Grune biotonne Witzenhausen.

Hoitink, H.A., A.G. Stone and D.Y. Han. 1997. Suppression of plant diseases by composts. HortScience 32(2): 184-187.

Ketterer, N., B. Fisher and H. Weltzien. 1992. Biological control of *Botrytis cinerea* on grapevine by compost extracts and their microorganisms in pure culture. In: K. Verhoeff, N. Malathrakis and B. Williamson (eds.), Recent Advances in *Botrytis* Research. Proceedings 10th International *Botrytis* Symposium, Heraklion, Crete, Greece, April 5-10, 1992, pp.179-186.

Stindt, A. and H.C. Weltzien. 1988. Der Einsatz von kompostextrakten zur bekampfun von *Botrytis cinerea* an erdbeeren - ergebnisse des versuchsjahres 1987. Gesunde Pflanzen 40: 451-454.

Thom, M and S. Moller. 1988. Untersuchungen zur wirksamkeit wasseriger kompostextrakte gegnuber edem erreger des echten mehltaus an gurken. Thesis. Gesamthochschule Kassel

Urban, J. and A. Trankner. 1993. Control of grey mould (*Botrytis cinerea*) with fermented compost/water extracts. In: N.J. Fokkema, J. Kohl and Y. Elad (eds.) Biological control of foliar and post-harvest diseases. Proceedings of a Workshop. West Palearctic Regional Section 16: 8-11.

Weltzien, H. 1991. Biocontrol of foliar fungal diseases with compost extracts. In: J.H. Andrews and S. Hirano (eds.) Microbial ecology of leaves. New York, NY, pp. 430-450.

Weltzien, H et al. 1989. Improved plant health through application of composted organic materials and compost extracts. 7th IFOAM International Scientific Conference, Burkina Faso, January 1989.

Weltzien, H. and N. Ketterer. 1986. Control of downy mildew, *Plasmopara viticola* (de Bary) Berlese et de Toni, on grapevine leaves through water extracts from composted organic wastes. Journal of Phytopathology 116: 186-188.