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Suppression of *Phytophthora infestans* in Potatoes by Foliar Application of Food Nutrients and Compost Tea

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Abstract: The efficacy of compost tea (CT), food nutrients (FD), and manzate (MZ) applied foliarly against late blight (*Phytophthora infestans*) of potato (*Solanum tuberosum* L.) 'Green Mountain' and 'Russet Burbank' was evaluated in greenhouse trials conducted in New Brunswick, Canada. Percent of late blight incidence and severity were assessed four weeks after treatment and inoculation. Relative to the untreated control treatments, MZ reduced late blight severity by 92% and 99%; CT reduced severity by 29% and 27%; and FD reduced severity by 22 and 35% in 'Green Mountain' and 'Russet Burbank', respectively. In a separate study on the cultivar 'Shepody' comprising of 13 different treatments including combinations of compost tea and food nutrients, treatment with a combination of compost tea and seaweed extract resulted in 36% reduction in late blight severity relative to the inoculated control treatment. The combinations of CT + whey, CT + potassium bicarbonate, CT + Neptune's, and CT + organic gem reduced disease severity by 21, 10, 10, and 5%, respectively, relative to the inoculated control treatment. The results of this study shed the light on the potentially positive effect of combinations of compost tea and food nutrients as an alternative, relatively cheap, and environmentally safe tool for late blight control in potatoes. Such new tools are essential for fungicide resistance management.

Key words: Compost tea, food nutrients, late blight, manzate, *Phytophthora infestans*, potatoes

INTRODUCTION

Potato late blight caused by the fungus *Phytophthora infestans* (Mont.) deBary, remains a disease of major concern throughout the world, costing growers tens of thousands of dollars for its control each year. The disease is often associated with the Irish potato famine in the 1840's. It was responsible for the occurrence of severe epidemics in Great Britain, Holland and Belgium during the same years it caused the Irish potato famine (Andrivon, 1996). The problem in controlling this disease has increased enormously over the years and the difficulty in its control has been associated with changes in populations of the pathogen (Cooke *et al*., 2006). The introduction of new genotypes of *P. infestans* to the United States and Canada during the late 1980's and 1990's coincided with an increase in the incidence and severity of late blight (Goodwin *et al*., 1995; Chycoski and Punja, 1996; Goodwin *et al*., 1998). Recent studies have shown that US-8 isolates (also known as A2 strain) are more aggressive on potato foliage and tubers than US-1 isolates (also known as A1 strain) (Kato *et al*., 1997; Lambert and Currier, 1997; Peters *et al*., 1999b). In Canada, the US-8 genotype has displaced US-1 in most potato production areas outside British Columbia (Peters *et al*., 1998; Peters *et al*., 1999a).

The late blight disease is identified by water-soaked lesions with chlorotic borders that are small at first, but expand rapidly. Under humid conditions, *P. infestans* produces sporangia and sporangiophores on the surface of infected tissue. This results in visible white sporulation at the leading edge of lesions. As many lesions coalesce, the entire plant can be destroyed in only a few days after the first lesions are observed. Potato tubers become infected when sporangia are washed from the foliage through the soil.

Infections begin in tuber cracks or lenticels, and infected parts of tubers turn reddish to purplish in color. Sporulation may occur on the surface of infected tubers in storage. These are often invaded by soft rot bacteria which rapidly convert the tuber pile into a smelly, rotten mass that must be discarded (Stevenson, 1993). Interest in the use of compost tea or organic tea in agriculture and horticulture has grown rapidly during the

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last decade. These products act as sources of plant nutrients and beneficial organic compounds that possess the ability to suppress plant pathogens (Anonymous, 2004). It is a well known fact that certain soil microbes have the capacity to suppress plant diseases (Cook and Baker, 1983; Adams, 1990). In studies conducted earlier, researchers have shown that organic tea or special compost extracts when applied on host plants have controlled certain plant diseases including apple collar rot, apple scab, grey mold, downy mildew, powdery mildew and damping-off (Weltzien and Ketterer, 1986; Budde and Weltzien, 1988; Chen *et al*., 1988; Andrews and Harris, 1992; Boehm *et al*., 1993; Elad and Shtienberg, 1994; BioCycle Staff, 1997).

Preparation of aerobic compost tea extract is done with a 24h extraction process by bubbling air through the slurry (Brinton *et al*., 1996; Al-Mughrabi, 2006) while the common preparation of compost extracts involves mixing of mature compost with tap water in an open container in varying ratios. After stirring the mixture, it is steeped at ambient temperatures for several days up to a week. The extract obtained is then filtered and later applied to foliage or drenched into the soil (Abbasi *et al*., 2002). In some cases, compost tea is mixed with additives which are added with a view of increasing microbial population densities during production (Scheuerell and Mahaffee, 2002). It is reported that the dominant microbial population in both aerated (Weltzein, 1991) and non-aerated (Ingham, 2000) compost tea is bacteria which could be a useful parameter that could aid in the measurement of plant disease. It is generally believed that higher level of disease suppression can be achieved by increasing the population of total and active bacteria in compost tea (Ingham, 2000), but the evidence to support these views is lacking.

In order to grow a potato crop and maintain quality and high yield, growers are required to follow a long and strict program which depends on frequent applications of costly pesticides (Stevenson, 1994). It is estimated that losses up to 22% can be incurred due to pressure posed by infestation with potato pests and diseases every year (Ross, 1986). Farmers rely on fungicides to protect their crop against late blight and most of the fungicides in use are protectants. In addition, the late blight pathogen has started developing resistance to available fungicides (Carter *et al*., 1982; Goodwin *et al*., 1996). In such a scenario, it becomes imperative to look for alternative methods to control late blight of potato. Manzate® 200 DF (Mancozeb 75.0%, Manganese equiv. 15.0%, Zinc equiv. 1.9%, and Ethylene bisdithiocarbamate equiv. 58.1%) is registered in Canada for use against early and late blight of potatoes. It would be advisable to test how efficacious the fungicide Manzate and compost tea are in protecting the potato plants from late blight. This is the first study to evaluate the efficacy of foliar applications of a large number of food nutrients, compost tea, and combinations of compost tea and food against late blight of potato.

MATERIALS AND METHODS

Experiment 1. Efficacy of Compost Tea, Food Nutrients and Manzate Against Late Blight:

Preparation of Aerobic Compost Tea:

Compost tea (CT) was prepared using a combination of three types of compost/organic materials, namely thermal compost, static wood chips compost (no turning occurred once the pile was formed), and vermi-castings. Compost additives including kelp, humates, rock dusts, grain/alfalfa meals, soluble plant sugar sources, and liquefied fish were added to non-chlorinated water and compost during the twenty four hour compost tea aerobic brewing cycle (Al-Mughrabi, 2006). For the foliar applications, soluble plant sugar sources, a natural yuccah surfactant, and liquefied fish were added as food to the compost tea prior to application.

Experimental Setup:

Greenhouse experiments were conducted using a 2 way randomized complete block design. The experiments consisted of two varieties of potato (Green Mountain and Russet Burbank) and four treatments: (1) untreated control inoculated with *Phytophthora infestans* (CI); (2) inoculated plants treated with manzate (MZ); (3) inoculated plants treated with food nutrients (FD); and (4) inoculated plants treated with compost tea (CT). Each treatment consisted of 4 replicates and each replicate consisted of 3 pots.

Seed potatoes were planted in classic plastic pots (8 inches in diameter) filled with peat moss soil mixture. Plants were watered when soil became light brown on the surface. Types of fertilizer added, rates, and dates of application are given in Table 1. All plants received the same amount of water and fertilizer regardless of moisture content except for the first calcium nitrate application.

Compost Tea Application:

Foliar applications of compost tea were done at a rate of 46.8 l ha^{-1} once a week starting 50 days after planting. A total of four foliar applications were made using a CO_2 sprayer with 15-20 psi pressure.

Table 1: Types of fertilizer, days of application, and concentrations added to soil using a standard maintenance procedure

Fertilizer	Days after planting	Concentration
NPK 10.7:11.8:11.8	At planting	1570 kg ha^{-1}
Calcium nitrate	26	150 ppm of calcium nitrate
Calcium nitrate	39	150 ppm of calcium nitrate
NPK 20-20-20	52	1 Tbsp/gallon, 200 ml per plant
Sulfuric acid	56	0.01% sulfuric acid
Ammonium sulfate	60 - 74	0.5 Tbsp/gallon; 200 ml per plant
Ammonium sulfate	75 - 82	1 Tbsp/gallon; 200 ml per plant

Growth Conditions:

Supplemental light was used whenever it was necessary with the help of HID lights. Opaque plastic was placed over the greenhouse to eliminate the need to vent. The HID lights were set to run from 6:30 a.m. to 6:30 p.m., regardless of the amount of sunlight present outdoors. Plastic tents were placed over the plants to raise the relative humidity to about 85% compared to 40-60% obtained without the tents. Average temperatures were 20ºC day and 18ºC night.

Environmental Conditions:

Potato plants in pots were placed on matting material and were maintained in open air with horizontal air flow (HAF) fans. The pots were placed on PVC rings to protect them from the damp matting material. The tents were closed during night time and were left open during the day. For inoculation, A2 strain of *Phytophthora infestans* from New Brunswick, Canada was used (1 x 10^4 zoospores ml^{-1}). Two liters of zoospore suspension solutions were sprayed on each variety (48 plants) until run-off using a CO_2 sprayer at 40 psi. A second inoculation was carried out using a hand held sprayer one week after the first inoculation. The tents were left closed to raise the relative humidity level within the greenhouse and were opened one day later. Disease severity and incidence were assessed one week after inoculation on a scale of 0-100% (Cruickshank *et al.*, 1982; Dorrance and Inglis, 1997). Percent disease incidence and disease severity were calculated relative to the inoculated control treatment and were used in the statistical analysis. Percent disease severity or incidence was calculated using the following formula: Severity or incidence (%) = (Incidence or severity in treatments/ incidence or severity in control) x 100. Data were statistically analyzed using CoStat (CoHort Software, Monterey, CA, USA) and the means were separated using LSD test at P=0.05.

Experiment 2. Effect of Combinations of Compost Tea and Food Nutrients on Late Blight Severity:
Experimental Setup:

The experiment was conducted using 'Shepody' variety of potato in a greenhouse with one way randomized complete block design. It consisted of thirteen treatments (control with *P. infestans* inoculation; CT= compost tea; CT+M = compost tea with molasses; CT+C = compost tea with cider; CT+W = compost tea with Whey; CT+OG = compost tea with organic gem; CT+ELS = compost tea with ELS; CT+V = compost tea with vinegar; CT+H = compost tea with humate; CT+N = compost tea with Neptune's; CT+SE = compost tea with soil extract; CT+PB = compost tea with potassium bicarbonate; and CT+SF = compost tea with super flow). Each treatment was replicated three times, and each replicate consisted of three plants. All thirteen treatments were inoculated with *P. infestans*.

Eight inch classic plastic pots were filled with peat moss soil mixture and were then planted with potato seeds. Plants were watered when soil became light brown on the surface. Treatment details for this trial are given in Table 2 and the details of different food nutrients used in the present trial are listed in Table 3.

Growth and environmental conditions during the experiment were similar to those followed in experiment 1 above. Disease severity was assessed one week after inoculation on a scale of 0-100% (Cruickshank *et al.*, 1982; Dorrance and Inglis, 1997). Percent disease severity was calculated relative to the inoculated control treatment and was used in statistical analysis. Data were analyzed using CoStat (CoHort Software, Monterey, CA, USA) and the means were separated using LSD test at P=0.05.

RESULTS AND DISCUSSIONS

Results:

Experiment 1. Efficacy of Compost Tea, Food Nutrients and Manzate on Late Blight:

Results of the analysis of variance (ANOVA) indicated that there were significant differences between treatments in their effect on late blight incidence (Table 4). The two potato varieties, Green Mountain and Russet Burbank did not differ significantly from each other with respect to blight incidence. All the treatments were significantly different from each other in their effect on late blight severity (Table 5).

Table 2: Treatment details to study the combined effect of compost tea and food nutrients on disease severity of late blight in potato

Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13
Compost Tea	0.5gal	0.5gal	0.5gal	0.5gal	0.5gal	0.5gal	0.5gal	0.5gal	0.5gal		0.5gal	0.5gal	0.5gal
Organic Gem	10 ml									C			
Neptune's		10 ml								O			
Vinegar			20 ml							N			
Whey				20 ml						T			
Potassium Bicarbonate					0.3 oz					R			
Seaweed Extract						2 gr.				O			
Super Flow							10 ml			L			
ELS								8 ml					
Cider											20 ml		
Molasses												10 ml	
Humate 85% Soluble													0.1 oz
Total Volume with water	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal	1.0gal

Table 3: Details of different food nutrients used in combination with compost tea

Treatment	Details
Organic gem	It is an all-natural fresh fish liquid fertilizer which has high quality organic product that gives excellent plant growth, rebuilds soil, and offers higher production yields
Neptune's	It is an all-natural fresh fish liquid fertilizer which has high quality organic product that gives excellent plant growth, rebuilds soil, and offers higher production yields
Vinegar	It is a liquid produced from the fermentation of ethanol which can be used as an organic herbicide
Whey	By-product of the manufacture of cheese or casein and whey protein is sold as a nutritional supplement
Potassium bicarbonate	It is made industrially from carbon dioxide (CO_2) gas and potassium hydroxide and can be used as a contact fungicide in a variety of crops
Seaweed extract	Seaweed is high in vitamins A, C and E which are potent anti-oxidants
Super flow	This is a natural surfactant made from yuccah and other saponins
ELS	This is a proprietary soil biology stimulant containing seaweed and other enzymes.
Cider	Fermented juice from apples with relatively high concentration of phenolics and antioxidants
Molasses	By-product from the processing of sugarcane or sugar beet into sugar and contains significant amounts of vitamins and minerals
Humate (85% soluble)	Contains good concentrations of humic and fulvic acids and is rich in natural chelate trace elements, such as Fe, Zn, Mg etc

Table 4: Analysis of Variance (ANOVA) table for overall late blight incidence in relation to compost tea, food nutrients and Manzate treatments

Source	DF	MS	F	P
Blocks	3	2.48	0.0689	ns
Main Effects				
Treatment (T)	2	43.3	0.0005	***
Variety (V)	1	0.13	0.7235	ns
Interaction				
T x V	2	0.13	0.8816	ns
Error	63			
Total	71			
Model	8	11.8	0.0005	***

Table 5: Analysis of Variance (ANOVA) table for overall late blight severity in relation to compost tea, food nutrients and Manzate treatments

Source	DF	MS	F	P
Blocks	3	2.7	0.0532	ns
Main Effects				
Treatment (T)	2	28.5	0.0005	***
Variety (V)	1	0.6	0.4470	ns
Interaction				
T x V	2	0.3	0.7617	ns
Error	63			
Total	71			
Model	8	8.3	0.0005	***

Among all treatments, disease incidence and severity for manzate (MZ) relative to the inoculated control treatment were significantly different in both potato cultivars compared to compost tea (CT) and food nutrients (FD) (Table 6). MZ reduced incidence and severity of late blight in Green Mountain cultivar by 92 and 92%, respectively. CT and FD reduced disease incidence by 17 and 17%, respectively, while the late blight disease severity was reduced by 29 and 22% by those treatments in Green Mountain potatoes (Table 6). In Russet Burbank, when MZ was used, late blight incidence and severity were reduced by 92 and 99%, respectively, in relation to the inoculated control treatment. Disease severity was reduced by 27 and 35% while disease incidence was reduced by 8 and 17% for CT and FD, respectively.

Table 6: Effect of compost tea, food nutrients, and Manzate on late blight severity and incidence of Green Mountain and Russet Burbank potatoes

Treatment[1]	Green Mountain		Russet Burbank	
	Disease incidence	Disease severity	Disease incidence	Disease severity
Compost Tea (CT)	83[a2]	71[a]	92[a]	73[a]
Food Nutrients (FD)	83[a]	78[a]	83[a]	65[a]
Manzate (MZ)	8[b]	8[b]	8[b]	1[b]
LSD @ 0.05%	30	33	24	23

[1]Each treatment was replicated four times. Percent disease severity or disease incidence was calculated relative to the inoculated control treatment.
[2]Within each column, means followed by same letter are not significantly different from each other at P=0.05.

Experiment 2.
Effect of Combinations of Food Nutrients and Compost Tea on Severity of Late Blight:

Results of the ANOVA indicated that there were significant differences among all thirteen treatments in their effect on late blight (Table 7). Among the thirteen treatments tested, the treatment receiving CT + seaweed extract (SE) was significantly superior to the rest of the treatments with respect to disease severity in Shepody potatoes (Fig. 1). CT + SE reduced late blight severity by 36% relative to the inoculated control treatment. Similarly, the combinations of CT + whey, CT + potassium bicarbonate, CT + Neptune's and CT + organic gem reduced late blight disease severity by 21, 10, 10 and 5%, respectively, relative to the inoculated control treatment (Fig. 1).

Table 7: Analysis of Variance (ANOVA) table for disease severity in Shepody potatoes treated with different combinations of compost tea and food nutrients

Source	DF	MS	F	P
Blocks	2	1.8	0.1970	ns
Main Effects				
Treatment (T)	11	4.6	0.0012	**
Error	22			
Total	35			
Model	13	4.1	0.0016	**

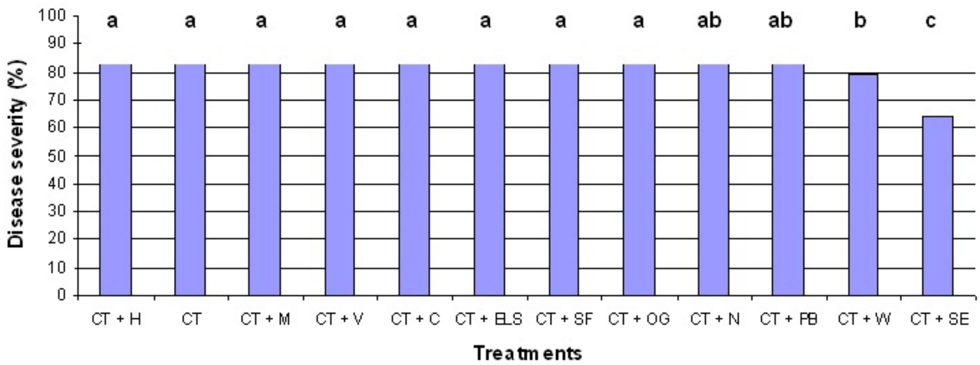

Fig. 1: Effect of combination of compost tea and other treatments on late blight severity in potato. CT: Compost Tea; M: Molasses; C: Cider; W: Whey; OG: Organic Gem; V: Vinegar; H: Humate; N: Neptune's; SE: Seaweed Extract; PB: Potassium Bicarbonate; SF: Super Flow. Means followed by the same letter are not significantly different according to LSD test at 0.05 probability level. Percent disease severity was calculated relative to the inoculated control treatment and was used in statistical analysis.

Discussion:

The application of compost tea has been shown to significantly suppress several diseases including gray mold, apple scab, collar rot, downy mildew, powdery mildew and damping-off (Weltzien and Ketterer, 1986; Budde and Weltzien, 1988; Chen *et al.*, 1988; Andrews and Harris, 1992; Boehm *et al.*, 1993; Elad and Shtienberg, 1994; BioCycle Staff, 1997). Compost tea coats plant surfaces or roots with living microorganisms and provides food for beneficial microbes. This aids in securing diverse and healthy food web community where symbiotic bacteria and fungi provide protection in the form of disease resistance. In general, the use of organic tea or compost tea extractions have been shown to result in modest to major control of several plant diseases including potato late blight (Ketterer and Weltzein, 1988; Weltzein, 1991; Biocycle Staff, 1997; Hoitink and Boehm, 1999; Abbasi *et al*., 2002; Stone *et al*., 2004; Al-Dahmani *et al*., 2005; Scheuerell and Mahaffee, 2006). Composted pine bark mix fortified with the biocontrol agent *Trichoderma hamatum* - 382 reduced the severity of bacterial leaf spot on radish, lettuce and tomato under controlled environmental conditions (Al-Dahmani *et al*., 2005). Plots amended with composted cannery wastes reduced the incidence of anthracnose fruit rot in tomatoes compared to non amended plots and resulted in a 33% increase in marketable yield (Abbasi *et al*., 2002). Modest control of powdery mildew and *Botrytis* on grapes was observed by application of aerated compost tea and non aerated compost tea (Travis *et al*., 2003).

In other studies, aerobic compost had a lesser effect in controlling apple scab, downy mildew, brown fruit rot and peach leaf curl (Wittig, 1996). Witting (1996) was of the opinion that microorganisms present in compost may be better adapted to a soil environment and may have greater potential when used as a drench in controlling soil-borne pathogens. Use of compost tea and other amendments have failed to significantly reduce black scurf, common scab and stem canker in plots where potato was grown every year while the same set of amendments showed significant disease reductions in potato following rotations with barley and clover (Larkin, 2007). In Rose plants, compost tea treated plots showed an increase in black dot severity from 10% in July to 30% in August and 70% in September (Cascadia Consulting Group, 2001). In a similar study conducted at the University of Washington, a compost tea trial was more successful in controlling the spread of rose diseases. This was attributed to a more fungal-dominated source of compost and weekly rather than bi-weekly tea applications (Cascadia Consulting Group, 2001). Similarly, the use of compost extracts under field conditions on tomato plants resulted in marginally effective control of bacterial spot on fruits under high disease pressure to ineffective control on foliage (Al-Dahmani *et al*., 2003).

In our study, manzate provided the best control of late blight, followed by compost tea and food nutrient treatments. Sturz *et al*. (2004) suggested that although foliar compost tea mixes may contain bacterial isolates with higher antibiosis ability against *P. infestans*, their populations can be significantly reduced after compost tea application. Such bacterial communities may be unable to get established on the foliar surfaces of potato plants or might be washed off at the time of application to foliage. Another reason suggested for reduced activity of compost tea in disease suppression is that the additives added to encourage microbial reproduction in compost tea might support saprophytic growth of plant pathogen and might neutralize the potential of biological control (Scheuerell and Mahaffee, 2004; Scheuerell and Mahaffee, 2006).

Additional research is needed in order to have a better understanding of the survival capabilities of beneficial organisms on leaf surfaces and host plant selection of microorganisms possessing ability to withhold competition from plant pathogens and become antagonistic to them. From the results of the present study, it can be concluded that treatments involving compost tea and food nutrients can reduce disease severity of late blight in potato plants. Among the 13 compost tea and food nutrient combinations used in experiment 2, treatment with a combination of compost tea and seaweed extract resulted in a 36% reduction in late blight disease severity relative to the inoculated control treatment. Treatment with a combination of compost tea and whey reduced disease severity by 21%. These treatments have good potential and should be fine-tuned in order to increase their efficacy against late blight and bring them to the market for commercial use. The findings in these studies indicate that foliar applications of combinations of compost tea and food nutrients are viable options for late blight control in potatoes.

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