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Late blight control alternatives for organic potato growers Project # - I-096

December 1,2008

Transmittal Notice

E.S. Cropconsult Ltd. has fulfilled all of the obligations set forth in the proposal and contract for the project: **Late blight control alternatives for organic potato growers.** There was one added treatment to the proposed list, at the request of Fraserland Organics, the application of Parasol weekly at $\frac{1}{2}$ of the recommended rate. The inoculum was to be cultured and sprayed on. There were some difficulties in culturing the organism. As an alternative the spores were spread manually using collected infected leaves (see report for complete method). There were 10 repeated plots of each treatment – fortunately, at two separate sites (5 at each), as the late blight inoculation was successful at only one of the sites.

LATE BLIGHT CONTROL ALTERNATIVES FOR ORGANIC POTATO GROWERS: 2008 TRIALS

Report to: Fraserland Organics and Certified Organic Association of BC

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ES CROPCONSULT LTD., 2008

SUMMARY

Organic potato production is a growing sector in the province of BC, with organic potato acreage increasing by 25% between 2004 and 2007. These organic potatoes face the same insect and disease pressures as conventional potatoes. The fungal pathogen *Phytophthora infestans* (Mont.) de Bary, causal organism of late blight, is the major disease affecting both conventional and organic potatoes on Canada's west coast. Lesions spread quickly in favourable conditions, resulting in rapid defoliation, yield loss, and plant death. While it is common in BC for growers of conventional and seed potatoes to rotate fungicides to prevent late blight, only one product, a formulation of copper hydroxide (Parasol WP), provides late blight protection for organic growers. While effective, copper use is restricted for organic production due to adverse effects on soil microbial communities and processes. The current study evaluated six alternatives to the current weekly copper spray program. These were 1) copper sprayed every two weeks, 2) copper sprayed weekly at half the standard rate, 3) copper sprayed in rotation with compost tea, 4) copper sprayed in rotation with Serenade, 5) compost tea sprayed weekly, and 6) Serenade sprayed weekly. These treatments were compared with the industry standard, copper sprayed weekly, and untreated control. A small-scale field trial consisting of 5 replications x 8 treatments, in a completely randomized design, with each treatment replicate consisting of a single plant, was maintained in Matsqui, BC. Treatment solutions were applied weekly using a SOLO backpack sprayer pumped to maintain full pressure. Plants were assessed weekly for late blight incidence and severity. Late blight from an infected field was introduced to the trial approx. 60 days after planting. Plants were watered overhead daily for the first week post-inoculation. All plants developed late blight infection by the final scoring date. Four alternative treatments, which included compost tea and Serenade sprayed in alternating weeks with copper, copper sprayed every 14 days, and copper sprayed weekly at half the standard rate, resulted in disease control equal to the industry standard. This result gives strong evidence that copper use can be reduced either in frequency or rate for late blight control in organic potato production. However no effective replacements for copper were identified.

INTRODUCTION

Potatoes are the largest field vegetable crop in BC, constituting over 1/3 of the province's vegetable production. As of 2003, growers in the Lower Mainland farmed 78% of the province's total acreage for table potatoes (Anon., 2003). Organic potato production is a growing sector in the province. Organic potato acreage farmed by Fraserland Organics, BC's major organic potato producer, increased by 25% between 2004 and 2007.

The fungal pathogen *Phytophthora infestans* (Mont.) de Bary, causal organism of late blight, is the major disease affecting both conventional and organic potatoes on Canada's west coast. Symptoms typically appear on older leaves shortly after the plant flowers, and following cool, wet weather. A typical lesion is chocolate-brown in colour surrounded by a pale green halo. The underside of an infected leaf may reveal a dense, white mycelium surrounding the lesion, in which the fungus is producing infective structures called sporangia. Lesions also commonly appear on petioles and stems of the potato plant. These lesions spread quickly in favourable conditions, resulting in rapid defoliation, yield loss, and plant death. Losses are particularly severe if an epidemic occurs early in the growing season. Infection may also develop on tubers during harvest and spread in storage, causing further losses. Further complicating late blight management, metalaxyl resistance and both A1 and A2 mating types have now been present in the Fraser Valley for more than a decade, and have been correlated with the fungus' improved ability to colonize a host plant and tolerate environmental stress (Chycoski and Punja, 1996).

While it is common in BC for growers of conventional and seed potatoes to rotate fungicides to prevent late blight, only one product, a formulation of copper hydroxide, provides late blight protection for organic growers. Although copper is an essential trace element, it is toxic at high levels (Yang et al, 1993). Copper has been found to accumulate at the soil surface and can be taken up in amounts potentially toxic to livestock if silage maize is grown on former organic orchards or vineyards (Moolenaar and Beltrami, 1998). Adverse impacts of residues on microbial communities and soil processes, human and animal health has led to a phase-out of copper use in organic

production in the EU (Leifert, 2002). For these reasons additional methods for organic late blight management are needed.

The use of biological organisms is one alternative method of disease control. Compost teas have been observed to suppress plant diseases by supporting either beneficial or benign microbial organisms, including yeasts, bacteria, and fungi, which colonize leaf or root surfaces, and compete with pathogens (Wickland et al, 2001). Research has found that metabolites produced by strain QST-713 of the bacterium *Bacillus subtilis* are the active ingredient in the product Serenade (Stephan et al, 2005). Serenade inhibited spore germination and growth of *P. infestans* in laboratory assays, and partial suppression of the disease was obtained on potted plants (Olanya and Larkin, 2004). Results of a 2005 E. S. Cropconsult field study suggested that biological control may play a role in reducing late blight symptoms. Treatments consisting of compost tea or Serenade sprayed in alternating weeks with copper controlled a late blight epidemic as well as weekly sprays of copper alone (Meberg and Syrový, 2005).

The objective of this project is to reduce copper dependency in organic potato production by reducing frequency of copper sprays, reducing concentration of copper used in weekly sprays, or by replacing copper sprays with an alternative with a different mode of action. The current study evaluated organically permitted late blight spray regimes that included copper sprays at reduced frequency and rates, and biological treatments, compost tea brewed on-farm and Serenade Garden Concentrate, alone or in weekly rotation with copper.

MATERIALS AND METHODS

Layout, Planting, and Maintenance

Two experiments were planted in Abbotsford, BC, on May 15, 2008 using organic seed potatoes (var. Gem Russet) supplied by Fraserland Farms. The potted plant experiment consisted of ten treatments replicated five times, arranged in a completely randomized design. Seed pieces were planted into 1 gallon pots containing a 50/50 mix of Sunshine Mix No. 4 and No Name brand potting soil. Pots were watered thoroughly after planting and maintained outdoors under natural light and temperature conditions.

The field experiment consisted of 8 treatments replicated five times, arranged in a completely randomized design. Each plot consisted of a single potato plant (i.e. 40 replicates/plants). Seed potatoes were hand-planted 6 inches deep, in rows 2.5 feet apart, with 2 feet between potatoes in the same row. A pre-emergence herbicide (Linuron) was applied May 29 for weed control in field plots. The herbicide was broadcast sprayed with a CO₂ back-pack sprayer using a single, 8001VS low-delivery nozzle. Product was applied at 3.0 L/ha in 400 L solution/ha with a surfactant (Activate) at 2.5 mL/L. The plots were hand-weeded for field bindweed on June 10. Plots were watered twice/week, in the evening, following potato emergence using overhead sprinklers.

Treatments

Treatments were applied weekly commencing on June 20 (Week 1), following the rotations summarized in Table 1. Plants were approximately 12 cm high at first treatment. Weekly preventive sprays, regardless of presence of late blight in the field, is standard grower practice in the Fraser Valley due to the aggressiveness of the late blight strains. Final treatments were applied on August 22. All copper treatments used the industry formulation of copper hydroxide, Parasol WP (NuFarm Canada). Compost tea was brewed on-farm in an aerated one hundred-gallon tank (Growing Solutions, Inc.), 24 hours before application. The tank was filled with municipal water at least one hour prior to brewing, and aerated to remove chlorine. Twenty litres of vermicompost (Earth Elixir Quality Compost Teas, Saltspring Island) were added to the tank in four mesh cylinders. Compost ingredients included cheese whey, manure, coffee grounds, burdock, marshmallow and comfrey leaves, straw, oyster shell, eggshell, and rock dust (Kimmel,

pers. comm). 1000 mL of Kelp Grow (Marine Bioprocessing) and 500 mL of Humic Acid were added as a microbial food source at the start of brewing.

Plants were sprayed to runoff with foliar treatments, using a SOLO backpack sprayer hand-pumped to maintain full pressure. Approximately 0.2 L of treatment solution was applied per plant. The company that supplied the compost recommended that we also try applying compost tea to the soil to gain maximum benefits from feeding soil microflora, and improving plant nutrition. For soil treatments (treatments 9 and 10 – potted plant trial only) one litre of compost tea was watered into soil using a measuring cup.

Table 1: Treatment schedule and rates. Treatments indicated with an asterisk were included in the potted plant trial only.

<i>Trt</i>	<i>Week 1</i>	<i>Rate</i>	<i>Week 2</i>	<i>Rate</i>
1	Copper (Parasol WP)	5g/L	Copper (Parasol WP)	5g/L
2	Municipal water	N/A	Copper (Parasol WP)	5g/L
3	Copper (Parasol WP)	5g/L	Compost tea	IN TEXT
4	Copper (Parasol WP)	5g/L	Serenade Garden Conc.	33mL/L
5	Compost tea	IN TEXT	Compost tea	IN TEXT
6	Serenade Garden	33mL/L	Serenade Garden	33mL/L
7	Municipal water	N/A	Municipal water	N/A
8	Copper ½ rate	2.5g/L	Copper ½ rate	2.5g/L
9	Compost tea (soil)	IN TEXT	Copper (Parasol WP)	5g/L
10	Compost tea (soil)	IN TEXT	Compost tea (soil)	IN TEXT

Inoculation

Trials were inoculated with late blight the week that blight first appeared in the field (Table 2). Late blight infected potato leaves and stems were collected from a grower’s field in West Delta, BC and stored for 24 hours in plastic bags with moist newspaper to encourage sporulation. *Phytophthora infestans* spores were introduced to potted and field trials by rubbing infected tissue onto leaves. The inoculation was repeated one week later when infection did not appear on trial plants. Inoculation took place in evenings between 8 and 10 pm to encourage spore survival. Plants were irrigated immediately after inoculation, and nightly for 1 week following inoculation.

Assessment

Plots were assessed weekly, prior to treatment, for development of late blight infection. Incidence and severity (degree of infection on a plant) were measured weekly. Severity was measured using a 1-9, percentage-based scale, where 1 represented a plant with more than 90% necrotic tissue, and 9 represented a healthy plant showing no late blight symptoms (Cruickshank et al., 1982).

Table 2: Summary of major trial events.

<i>Event</i>	<i>Date</i>
<i>Planting</i>	<i>May 15</i>
<i>First treatment and scoring</i>	<i>June 20</i>
<i>First appearance of blight in field</i>	<i>July 7</i>
<i>1st Inoculation of trial</i>	<i>July 11 (field)/12 (potted)</i>
<i>2nd Inoculation of trial</i>	<i>July 17 (field) /18(potted)</i>
<i>First appearance of blight in trial</i>	<i>July 25 (field trial only)</i>
<i>Final treatment and scoring</i>	<i>August 22</i>

Analysis

Statistical analyses were performed using JMP IN version 4.0.3 (SAS Institute Inc., 2000). Late blight incidence data were summarized by counting weeks between second inoculation and plant infection and analyzed using one-way ANOVA. Severity data were analyzed using repeated-measures MANOVA. A separate one-way analysis of variance was conducted for each date (profile analysis) following significant treatment x time interaction effects in the MANOVA model. Post-hoc analysis of differences between means was performed using the Tukey-Kramer HSD test ($\alpha=0.05$).

RESULTS

1. Potted Plant Trial

Late blight infection did not occur in any treatments in the potted plant trial, so no further analyses were performed for this trial.

2. Field Trial

Incidence

All plants in the trial area developed late blight infection over the course of the trial. All plants were infected by August 15 (Fig 1). There was no significant effect of treatment on number of weeks between inoculation with late blight and plant infection (Fig 2; $F_{7,32} = 1.65$, $P = 0.16$).

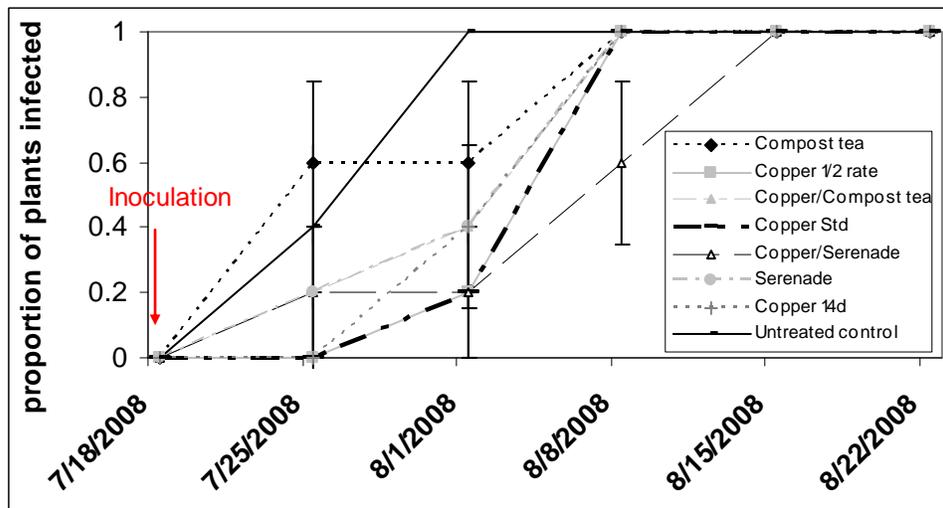


Figure 1: Spread of late blight infection in field trial plots. Data points represent proportion of plants with late blight infection \pm standard error mean (N=5 plants for each treatment).

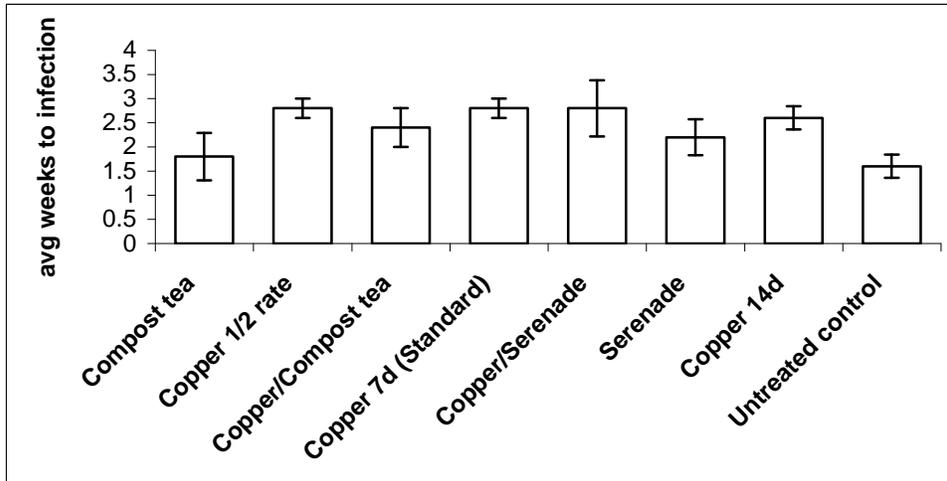


Figure 2: Average number of weeks between plant inoculation and infection. Columns represent the average number of weeks between plant inoculation and late blight infection \pm standard error mean (N=5 plants for each treatment).

Severity

There was a significant treatment x time interaction (Fig. 3; Wilks' $\lambda = 0.07$, $F_{28, 106} = 4.16$, $P < 0.0001$) on late blight severity, indicating that treatment differences changed over the course of the trial. Percentage of necrotic tissue per plant due to late blight increased in all treatments over time (Fig 3).

To understand the progress of the disease in the different treatments over the course of the study a profile analysis was conducted, with each date analyzed separately. From June 20 to August 1 there were no significant differences among treatments ($p > 0.05$ for all seven dates). By August 8 late blight severity was significantly lower in plots treated with the rotation of copper with Serenade than in plots treated with compost tea or Serenade only, but none of the treatments was different than the control (Fig 4; $F_{7, 32} = 2.47$, $P = 0.04$). By August 15, late blight severity was significantly lower in plots treated with a rotation of copper with compost tea in alternating weeks, Parasol sprayed weekly at half the standard concentration, copper sprayed every 14 days, and the standard weekly copper treatment than in the untreated control (Fig 5; $F_{7, 32} = 8.18$, $P < 0.0001$). By the end of the trial on August 22 all treatments that included copper in the rotation had significantly lower late blight severity than the untreated control (Fig 6; $F_{7, 32} = 24.25$, $P < 0.0001$). All of the reduced copper treatments - copper in alternating weeks with compost tea or Serenade, copper sprayed every 14 days, and copper sprayed weekly at half the

industry rate - had similar disease levels to the industry standard of copper sprayed weekly.

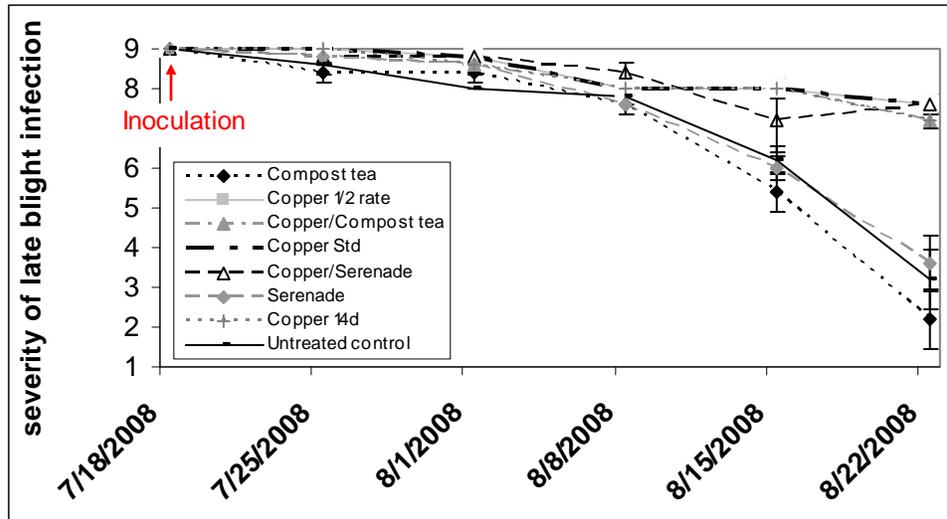


Figure 3: Development of late blight epidemic between July 25 and August 22 in field trial. A score of 9 indicates a healthy plant, while a score of 1 indicates a plant with more than 90% necrotic tissue due to late blight infection.

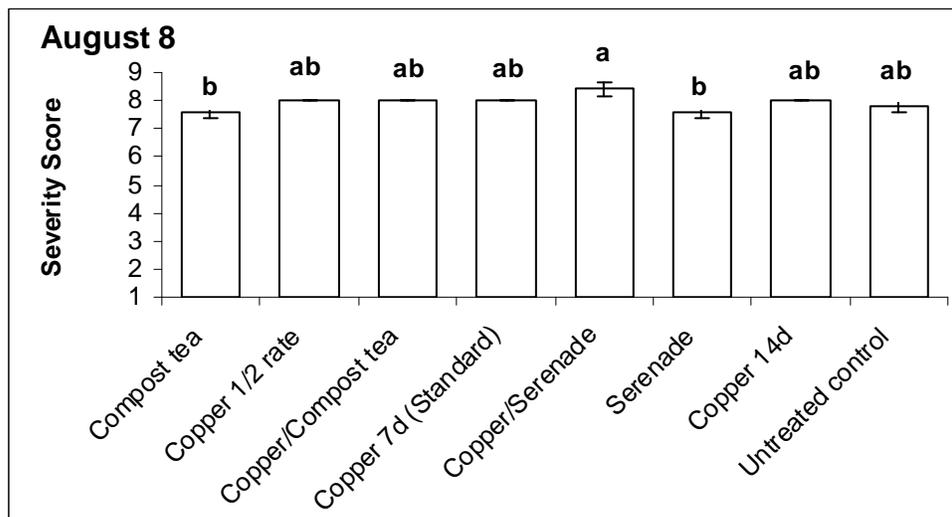


Figure 4: Late blight severity in field trial on August 8. Error bars represent standard error mean. Severity was measured on a 1-9 scale, where 9 indicates a healthy plant, and 1 indicates a plant with over 90% of area infected. Means denoted by the same letter are not significantly different at $\alpha = 0.05$ (Tukey-Kramer HSD test).

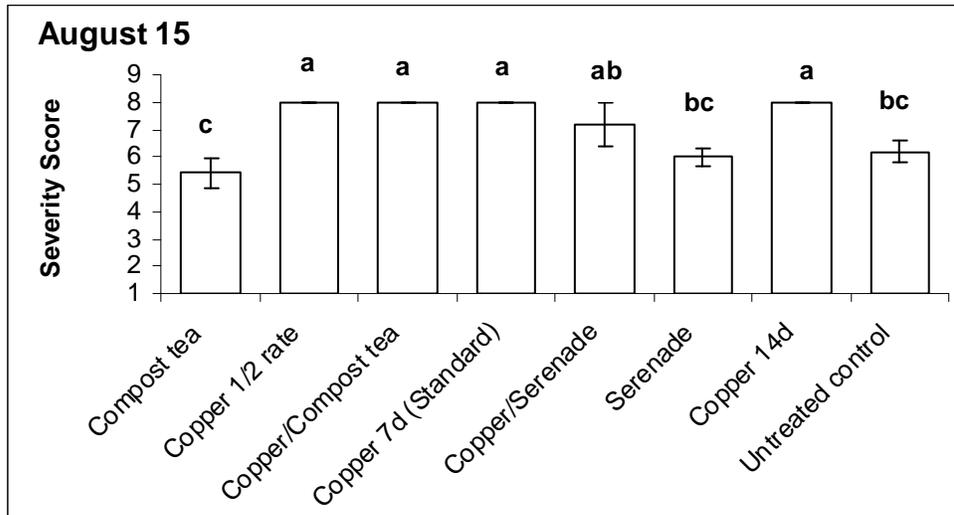


Figure 5: Late blight severity in field trial on August 15. Error bars represent standard error mean. Severity was measured on a 1-9 scale, where 9 indicates a healthy plant, and 1 indicates a plant with over 90% of area infected. Means denoted by the same letter are not significantly different at $\alpha = 0.05$ (Tukey-Kramer HSD test).

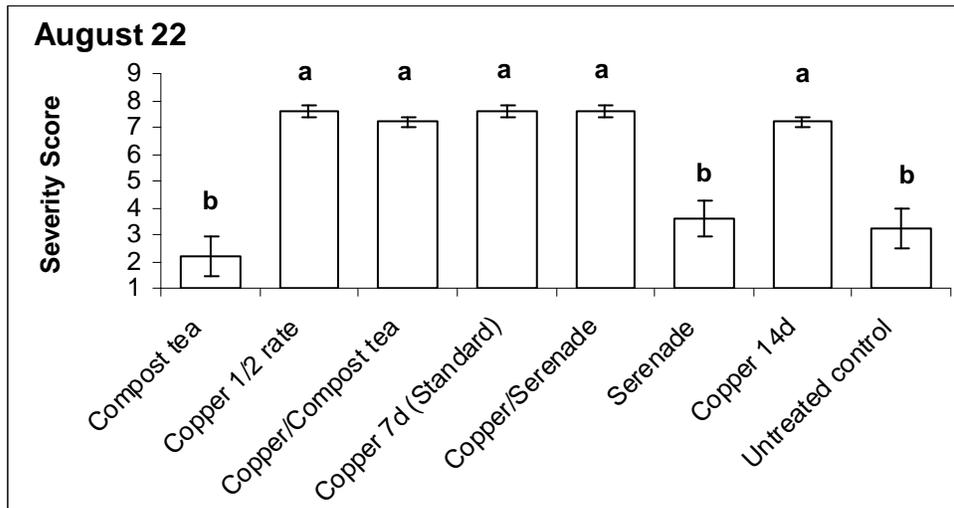


Figure 6: Late blight severity in field trial on August 22. Error bars represent standard error mean. Severity was measured on a 1-9 scale, where 9 indicates a healthy plant, and 1 indicates a plant with over 90% of area infected. Means denoted by the same letter are not significantly different at $\alpha = 0.05$ (Tukey-Kramer HSD test).

DISCUSSION

A 2005 ES Cropconsult study found that plots treated with copper in alternating weeks with compost tea or Serenade, showed significantly lower disease incidence and severity than the water-treated control (Meberg and Syrový, 2005). The two rotations that included copper did not differ significantly from weekly copper treatment, the industry standard, in late blight incidence or severity (Meberg and Syrový, 2005). This result suggested that copper use could be reduced by as much as half, and effective late blight control maintained, by substituting every second spray with compost tea or Serenade.

The present study was designed to confirm that these treatments effectively controlled late blight, and to test whether substituting sprays with compost tea or Serenade, gave any added benefit compared with spraying copper either less frequently (every second week), or at a reduced concentration. Again copper sprayed in alternating weeks with compost tea or Serenade gave late blight control equal to the industry standard. In addition the new 2008 treatments, copper sprayed every second week or copper sprayed weekly at half the standard rate, also gave late blight control equal to the industry standard. As in 2005, compost tea and Serenade sprayed alone weekly, were not effective controls.

This study gives strong evidence that copper use can be reduced and effective blight control still maintained. However it also finds that compost tea and Serenade are not effective replacements for copper when used alone. In addition, rotating compost tea or Serenade with copper gave equal suppression to the treatment that simply eliminated every second copper spray. Thus it appears highly likely that the late blight suppression observed is due to the copper only.

Reducing the interval of copper sprays to every 14 days was effective in suppressing late blight in both 2005 (natural infection in commercial potato field) and 2008 (inoculation in field plots). The effectiveness of the 2-week copper rotation occurred regardless of whether another product (Serenade or Compost tea) or only water was sprayed between copper sprays. However there are some caveats to our results that may not make a 14-day interval appropriate for all growers. First, in both years trials were conducted on determinate potato varieties - Russet Norkotah (2005) and Gem

Russet (2008) – both of which have a sparser, more open canopy. Growers may get different results using indeterminate varieties. This is because the plant could produce more unprotected foliage in two weeks, especially in June or July, than the varieties tested in our study. Copper fungicides are effective by providing a barrier between the plant and penetration by the fungus and a two-week spray interval may result in infection of new foliage. Second, we were likely getting very thorough coverage with our backpack applicator in small plots, compared to the application equipment used by growers. A 14-day interval may be too long if spray coverage is not thorough.

Although spraying copper weekly at half the industry rate was an effective treatment in this trial it is not one that is recommended for growers. In general using products at rates less than (or more than) that recommended by the manufacturer is not recommended, as half rate exposure can potentially enhance the development of resistance. Although resistance to copper has not been documented for *P. infestans* or any other fungi, some plant pathogenic bacteria, e.g. *Pseudomonas syringae*, have developed resistance (Vanneste and Voyle 2003). A final note is that while effective treatments to reduce copper use were identified, the two replacements examined in this study – Serenade and compost tea – were not effective. Further research screening new treatments, biological or otherwise, should be conducted to help reduce copper dependency in organic potato production.

ACKNOWLEDGEMENTS

The authors would like to thank Fraserland Organics for donation of organic seed potatoes, access to compost tea brewing facilities, technical advice, and financial contributions. Dr. Janice Elmhirst (Elmhirst Diagnostics and Research) supplied field space, inoculated, and maintained the field trial. COABC's OSDP fund helped fund this research. Thanks to Dr. Renee Prasad for technical advice and editing and ES Cropconsult staff for their various contributions to this trial.

REFERENCES

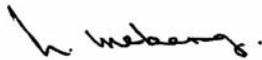
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**Financial Statement – OSDP Project # I-096 – Late blight control alternatives for organic potato growers.
December 1, 2008**

Income Source	Date	Cash	In-Kind	Total
Fraserland Organics	May 1, 2008 (in-kind potatoes; compost tea throughout the trial) June 1, 2008 (cash)	\$3,950.00	\$900.00	\$4,850.00
Elmhirst Diagnostics	July, 2008		\$1,000.00	\$1,000.00
OSDP	May 21, 2008	\$3,350.00		\$3,350.00
OSDP	Still to come	\$2,500.00		\$2,500.00
Total		\$9,800.00	\$1,900.00	\$11,700.00

Project Costs	Date	Equipment/Supplies	Salaries/Consultant	Travel	Sub total cash	In-Kind	Total
Plot Rental	May 27, 2008 (50%) & Nov 1, 2008 (50%)		\$1,200.00		\$1,200.00		\$1,200.00
Pots Flags Compost	May-August	\$150.00 (actual was \$388.84)			\$150.00		\$150.00
Elmhirst Diagnostics	Culture – july					\$1,000.00	\$1,000.00
Training	May 2008				\$1,000.00		\$1,000.00
Labour	May – Sept		\$5,400.00	\$1,100.00	\$6,500.00		\$6,500.00
Report	Oct-Nov		\$900.00	\$50.00	\$950.00		\$950.00
Potatoes	May 1, 2008					\$100.00	\$100.00
Comp. Tea	May-August					\$800.00	\$800.00
Totals		\$150.00	\$7,500.00	\$1,150.00	\$9,800.00	\$1,900.00	\$11,700.00

Signed:



Dated: December 1, 2008