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COMPARISON OF COMPOST TEA AND BIOLOGICAL FUNGICIDES FOR CONTROL OF EARLY BLIGHT IN ORGANIC HEIRLOOM TOMATO PRODUCTION

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COMPARISON OF COMPOST TEA AND BIOLOGICAL FUNGICIDES FOR CONTROL OF EARLY BLIGHT IN ORGANIC HEIRLOOM TOMATO PRODUCTION

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ABSTRACT

The efficacy of compost tea was evaluated and compared alone and in combination with two biofungicides Serenade Max™ and Sonata™ for control of early blight caused by the fungal pathogen *Alternaria tomatophila* on tomato *Solanum lycopersicum* (L), heirloom cultivar `Cherokee Purple'. Results of field experiments over two growing seasons indicated that compost tea provided a low level of protection against early blight. The results were variable; most likely due to dry conditions and the presence of bacterial wilt the first year and tomato spotted wilt virus the second year. In both 2006 and 2007 field trials compost tea was not statistically significant compared to the water control and other biofungicide treatments. Furthermore, in the field experiments, combination with commercial biofungicides Serenade Max™ and Sonata™ did not appear to improve the effectiveness of compost tea. In contrast, greenhouse disease control efficacy trials and pathogen germination laboratory experiments demonstrated significant effects of compost tea against the tomato early blight pathogen *A tomatophila.* Furthermore, results indicated that the efficacy of compost tea was improved when combined with the biofungicides. These results indicate that the use of compost tea for control of tomato early blight disease may be of some benefit to greenhouse tomato growers, and to growers of organic field tomatoes who are limited in their disease management options.

DEDICATION

To my father Norike and uncle Vahan and their family who grew up throughout the Great Depression, who subsisted off the land they lived on and who were models of self sufficiency and sustainability. To my daughter Kriya who begins her life surrounded by nature; who is inquisitive about the natural world.

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CHAPTER I

INTRODUCTION

Farm stewardship from the view point of environmental conservation can be seen throughout ancient agricultural societies of the world. Soil amendments have suppressed the erosive effects of tillage and the depletion of soil fertility due to generations of farming practices (Columella, 1941; King, 1911). Many of these ancient agricultural methodologies have recently gained favor over post-World War II mechanized farming methods that employ high energy inputs of manmade fertilizers, chemical pesticides and fossil fuel. One of the core concepts of organic farming that developed is the idea of recycling or the law of return (Howard, 1943) of on-farm products through composting. Prior to the turn of twentieth century complaints about soil infertility following the introduction of chemical fertilizers had prompted a series of lectures in 1924 by Rudolph Steiner (Diver, 1999) who introduced the concept of biodynamic farming to include composted materials applied in solid form as soil amendments and in liquid form as compost extracts. Compost teas have also been evaluated as an alternative to conventional fungicides for control of a variety of plant pathogens (Al-Mughrabi, 2006, Scheuerell and Mahaffee, 2006, Scheuerell and Mahaffee, 2004, McGrath, 2004, Al-Dahmani et al., 2003) and as a source of soluble nutrients which can be used as a liquid fertilizer (Diver, 2002).

Another benefit resulting from the application of compost as a soil amendment or as compost tea is the enhancement of microbial diversity in the field or garden. Studies have shown the declining of biodiversity can alter the performance of ecosystems (Naeem, 1994). A well-balanced agro-ecosystem with a broad spectrum of biological diversity can

act in self-regulation of the system (Vilich and Sikora, 1998). Creation of habitat to enhance the chances for survival and reproduction of beneficial organisms is a concept included in the definition of natural biocontrol (Dufour, 2001).Where soil amendments and foliar sprays are being utilized there is an emergence of biodiversity at the root and leaf surface that has potential for exploitation against many common pests and pathogens known to inhibit vegetable productivity.

Compost tea as an extract or leachate can be derived from composted plant or animal waste. Such organic matter has been decomposed by soil micro-fauna such as bacteria, fungi, nematodes, and soil arthropods. Heat is generated in the compost mixture by the activity of the organisms which accelerates the decaying process. Mechanistically, two methods of producing compost tea are non-aerated and aerated extracts. Non-aerated compost tea or "passive" compost tea (Diver, 2002) uses organic composted material which is steeped in water and is incubated over a defined period (Sheuerell and Mahaffee, 2006). In contrast, aerated compost tea, involves an "active" brewing process, in which the composted material is contained in a mesh bag and placed in a brewing device that contains water. Oxygen is pumped in to the filtered brewer to loosen microorganisms from the composted material and to supply needed oxygen for the aerobic dependent microbes; i.e. bacteria, protozoa, fungi and nematodes in the tea. The more diverse community of microorganisms extracted and grown under aerobic conditions, the greater the disease suppression will be and more nutrients will be retained. (Soil Food Web, 2007) The compost is "brewed" usually over a 24 hour period to allow the microorganisms to stabilize before being removed from the aeration brewer and transferred to a spray tank (Soil Food Web, 2007).Often, the compost contains adequate

food for microbial growth (Soil Food Web, 2007) but the addition of feed stock such as kelp, molasses, humic-fulvic acids and rock dust encourage high microbial populations (Grace, 2005). For control of plant pathogens the compost extract or "tea" can be applied and has been shown to be effective as a foliar spray (Scheuerell and Mahaffee, 2006) or as a soil drench application to the plant root zone or rhizosphere (Al-Mughrabi, 2006). On-farm production of compost tea can be cost effective and is known to be used by small and large scale farming operations as reported by Diver, (1998).

For plant disease control it has been suggested that minimum titers of microbial fauna in a milliliter of compost tea should be 10-150 µg of active bacteria, 150-300 µg of total bacteria, 2-10 µg of active fungi, 5-20 µg of total fungi, 1,000 flagellates, 1,000 amoebas, 20-50 ciliates and 2-10 beneficial nematodes (Diver, 2002). Several mechanisms involved in the antagonistic activity of beneficial microbes from compost tea including competition for nutrients, site exclusion, production of inhibitory metabolites, and parasitism (Elmer and Reglinski, 2006). Moreover, compost extracts have been shown to induce natural plant defenses against pathogens (Zhang et al., 1998). Compost teas produced from composted organic material with recommended carbon to nitrogen ratios of 30:1 (South Carolina Department of Health and Environmental Control, 2004) typically contain a diverse mixture of active micro-flora and fauna including bacteria, fungi, protozoa and nematodes These beneficial organisms occupy spatial niches on the leaf surface and feed on leaf exudates that pathogenic organisms would otherwise feed on to prosper; other microbes directly interfere with pathogenic organisms through antagonism(Diver, 2002).

First described by Smith (1919) as the use of natural enemies to control insect pests, according to DeBach (1964), biological control is the action of parasites, predators or pathogens in maintaining another organism's population density at a lower average than would occur in their absence. As of 2001 over 80 biological disease control products were marketed worldwide (Paulitz, 2001). The use of fungal and bacterial strains as biological control agents has received much recent attention because of their ability to suppress a variety of plant diseases (Romero et al.,2007). Some of the microbial taxa that have been successfully commercialized and are currently marketed as EPA-registered biopesticides in the United States include bacteria belonging to the genera Agrobacterium, Bacillus, Pseudomonas, and Streptomyces and fungi belonging to the genera Ampelomyces, Candida, Coniothyrium, and Trichoderma (Gardener and Fravel, 2002). Commercially available biofungicides such as Serenade Max® and Sonata® (AgraQuest, Davis, CA). have been utilized by both conventional and organic growers for disease control on a variety of vegetable crops against diseases such as early blight caused by Alternaria tomatophila (Zitter, 2005) and late blight caused by Phytophthora infestans (Stephan et al., 2005).

The bacterial strain used to produce Serenade Max is *Bacillus subtilis* QST-713 which exhibits activity against fungal pathogens through the production of lipopeptide compounds described by Marrone (2002). *B. subtilis* has been known to produce detergent-like lipopeptides such as surfactin (Arima et al., 1968) as well as other lipopeptides such as agastatin and iturin which are metabolites that have antibiotic and biosurfactant properties that inhibit germ tube growth and spore formation and may also interfere with attachment of the pathogen to the plant (Marrone, 2002). Biosurfactants are

microbial amphiphilic polymers and polyphilic polymers that tend to interact with the phase boundary between two phases in a heterogeneous system, defined as the interface (Rodrigues et al., 2006) e.g. cell wall. Surfactin has been shown to have hemolytic (Kratch et al., 1999) antiviral, (Vollenbroich et al., 1997a; Kratch et al., 1999), antibacterial (Vollenbroich et al., 1997b; Beven and Wroblewski, 1997) and along with iturin, antifungal (Bonmatin et al., 2003) properties. Although other modes of action against pathogenic fungi may occur including nutrient competition, exclusion, or induction of plant resistance, the metabolites produced by *B. subtilis* appear to be the effective component of the formulation and not the micro-organism itself (Stephan et al., 2005). The mode of action of the *B. pumilis* strain in the product Sonata results from production of a glucosamine analogue that interferes with the enzyme glucosamine-6-phosphate synthase and prevents phosphorylation of glucosamine in cell wall formation (Dennis Long, AgraQuest, personal communication).This mode of action has been described by Wojciechowski et al. (2005) and Janiak, et al.,(2002).

The objective of this study is to determine the efficacy of compost tea applied as a foliar spray for control of key fungal diseases common in organic tomato production; specifically early blight (EB) caused by the fungal pathogen *Alternaria tomatophila*. Tomatoes in South Carolina are produced on approximately 3000 acres with an annual value of $18.1 million (NASS, 2006). EB is an economically important disease throughout the southeastern United States and much of the world wherever tomato crops are grown under hot and humid conditions (Simmons and Roberts, 1993).

Environmental conditions in South Carolina, and the southeast, are conducive for EB proliferation. EB has the ability to grow over a wide range of temperatures (4-36°C)

(Pound, 1951), but 24-29^{o}C/75-84^{o}F is conducive to infection (Jones, 1991). Conidia will germinate within 40 minutes in the presence of available moisture at 90% relative humidity or greater (Sherf and Macnab, 1986, Kemmitt, 2002). Dissemination of the pathogen throughout the plant occurs acropetally from the lower leaves by wind and splashing rain and all above ground parts can be affected (Sherf and Macnab, 1986) Furthermore, older leaves are more susceptible to early blight, although tomato plants are susceptible at all growth stages (Vloutoglou and Kalogerakis, 2000). Infection occurs via germ tubes that penetrate the leaf epidermis directly or enter through stomata (Kemmitt, 2002). Initial symptoms on leaves appear as small 1-2 mm black or brown lesions (Kemmitt, 2002) Lesions greater than 10 mm in diameter often have dark pigmented concentric rings (Kemmitt, 2002). The fungus can overwinter on infected plant debris in soil by developing chlamydospores that can infect tomato plants the following year. Secondary infections can occur from the local dissemination of conidia (Baird, 2004) and can lead to complete defoliation of plants.

Alternaria solani was originally identified by Ellis and Martin (1882) who described the conidia of the pathogen found growing mostly on the under surface of eroded spots and faded portions of dying leaves of potato *Solanum tuberosum*, *Alternaria tomatophila* has distinguishing morphological and cultural differences compared to *A. solani.* Morphological differences of *A. tomatophila* conidia include one to five long filiform beaks that taper abruptly from the site of origin on the body apex. This contrasts with *A. solani* as the beaks in this species appear sturdier because they typically tapers gradually from a broad base (6-8μm) on the body apex as described by Simmons and Roberts (1993). The conidia of *A. tomatophila* are transparent pale tan with outer walls

that appear to be smooth (Simmons and Roberts, 1993) opposed to the darker phenotype of *A. solani* that appear golden brown (Ellis and Ellis, 1985). It has been reported that EB lesions often show concentric rings of death and desiccation as leaf spots enlarge and these may or may not bear conidia in nature (Simmons and Roberts, 1993). In culture, isolates of *A. tomatophila* do not sporulate as readily as *A. solani* produce smaller numbers of conidia on potato carrot agar (PCA) and V-8 agar (Simmons and Roberts, 1993) and have a tendency to grow fewer conidia under humid conditions (Giner and Gacia, 1994). Furthermore, lack of aeration *in vitro* has been shown to limit conidial development (Rotem, et al., 1978) However, abundant spore have been cultured on fresh modified cornmeal agar (MCMA) grown at 24^{o} C with a photo period of twelve hours (Spletzer and Enyedi, 1999) and with scarification (Simmons and Roberts, 1993).

The growing interest in biological disease control is due in part to growth trends in the organic food industry. Certified organic crop acreage in the U.S. has increased steadily and the organic industry grew overall by 17% to reach $14.6 billion in consumer sales in 2005 (OTA, 2006).Organic and sustainable farming practices have gained favor in the agriculture community because of increasing public concerns over the negative health and environmental impacts of pesticides and synthetic fertilizers. Furthermore, public concern over genetically modified crops and increasing demand for more flavorful vegetable varieties has prompted a resurgence of popularity for heirloom tomato cultivars such as Cherokee Purple. Solanaceous plants such as tomato are excellent model systems to study plant-pathogen interactions (Miessner, et al, 1997). Heirloom varieties offer little or no disease resistance (Gardner and Davis, 2005), as they have not been bred through hybridization to contain specific genes required for resistance to EB. This makes them

ideal for biological control studies as heirloom varieties are susceptible to infection by *A. tomatophila* which causes EB.

In the past, claims that organically grown products are healthier have been somewhat anecdotal. Recent studies have shown an increase in secondary plant metabolites such as flavonoids in organically grown tomato (Mitchell et al., 2007; Chassy et al., 2006). These flavonoids encompass a large group of phenolic compounds that demonstrate in vitro antioxidant activity (Pietta, 2000). The benefits of antioxidants have been widely discussed in clinical and nutritional literature to benefit human health (Halliwell, 1996, Narasimhan et al., 1995, Scalbert et al., 2005).

CHAPTER II

MATERIALS AND METHODS

Preparation of Compost Tea and Biofungicides

The compost used to prepare compost tea was obtained from a commercial source (The Nematode Tea Kit; Clarke Sod Farms, Bridgeton, N.J.). The compost composition included tree bark, leaves, grass clippings and vermicompost (worm castings) from worms fed on pumpkins. At Clarke Sod Farms the compost was heated naturally in windrows by the decomposition of organic matter from bacteria, fungi and soil arthropods to 69^{o}C for three days and turned twice with a tractor front end loader. Additional nematodes were added from decomposing leaf debris or leaf duff from differing tree species and added to the vermicompost after the thermal process. The nematode inoculum was then allowed to breed for three months within the vermicompost before it was added to the windrow composted mixture. Approximately 2.75 kg of prepared compost was placed in a fine nylon mesh bag and shipped weekly to Clemson for experiments.

A 95 L compost tea brewer (System 25 ™, Growing Solutions Inc. Eugene, OR) was used to produce the aerated compost tea for experiments. After filling the brewer tank with municipal water the water was dechlorinated by oxygenation (i.e. running the brewer air pump for 24 hours) before adding compost within the nylon mesh bag for brewing. The compost was brewed for 24 hr at which time a microbial food supplement, consisting of a mixture of 113.4 g humic acid, 113.4 g sea kelp and 453.6 g rock dust derived from volcanic ash, was added as per recommendations from Clarke Sod Farms.

The compost was brewed for an additional hour after addition of the food supplement and then the liquid extract was drawn off for use in experiments.

Commercial biofungicides used in experiments included Serenade® Max (AgraQuest Inc., Davis, CA.) applied at a concentration of 7.49 g/L and Sonata® (AgraQuest Inc., Davis, CA.) applied at a concentration of 10.57 ml/L. Concentrations used in experiments were based on manufacturer recommendations. Both biofungicides were diluted using a municipal water source; neither was dechlorinated.

Field Trial 2006

Field experiments were conducted at the Clemson University Calhoun Field Student Organic Farm, a certified organic research and teaching farm on the Clemson University campus. Tomato (*Solanum lycopersicum* cv. 'Cherokee Purple') transplants were grown in a certified organic greenhouse at Clemson University. Seeds were obtained from Seeds of Change (Gila, NM). Each treatment plot consisted of ten plants spaced 45.7 cm apart within a 4.32m long bed with 91.4 cm between beds within each row. The eight treatments were replicated four times in a randomized complete block design (RCBD) for a total of 32 treatment plots.

The treatments consisted of a water control, compost tea (CT), Serenade Max and CT + Serenade Max applied every five days, alternate applications of CT and Serenade Max every five days; and applications of Serenade Max, CT and CT + Serenade Max applied every 10 days. In accordance with farm practices tomatoes were grown on red plastic mulch with drip irrigation. Tomato seedlings were transplanted at 8-10 weeks of age to the field. Each hole was dug 15 cm deep with a planting auger. Approximately 60

ml of fertilizer (Earth Friendly All Purpose 5-5-3, Fertrell, Bainbridge, PA.) was placed into the hole before the seedling was planted. In this experiment the treatments were evaluated against naturally-occurring fungal disease. Spray treatments were applied to runoff using a CO_2-backpack sprayer with a pressurized boom and 1-3 nozzles, depending on stage of plant growth, to cover plants completely. Spray volumes ranged from 94.6-246 L/ per acre during the trial.

Visual observations of every plant for disease symptoms characteristic of fungal infection were taken every 5 days using a percentage rating scale (Table I). Statistical analysis of rating values was performed using an Randomized complete block design (RCBD) model and analysis of variance (ANOVA) followed by Fisher's least significant difference (LSD) test to compare treatment means (Flaherty et al.,2000),(SAS 9.1, Cary, NC). Linear contrasting of group treatment mean values was calculated for comparisons of all combinations of treatments.

Rating Scale of Plant Disease Severity			
Rating Scale	Percentage(%) of Disease Severity	Rating Scale	Percentage(%) of Disease Severity
0	0	11	55
1	5	12	60
2	10	13	65
3	15	14	70
4	20	15	75
5	25	16	80
6	30	17	85
7	35	18	90
8	40	19	95
9	45	20	100
10	50		

Table 1.

Field Trial 2007

Field experiments in 2007 were conducted as in 2006 with the following exceptions: The eight treatments consisted of water, compost tea (CT), Serenade Max, Sonata, CT + Serenade Max, CT + Sonata, CT alternated with Serenade Max and CT alternated with Sonata. Treatments were applied every 5 days. A field collected isolate of *Alternaria tomatophila* was provided by Dr. Kelly Ivors (North Carolina State Mountain Horticulture Crops Research and Extension Center, Fletcher, NC). Sporulation of *A. tomatophila* cultures was achieved by combing methods from several references. Isolates were cultured on modified cornmeal agar (MCMA), (17 g/L cornmeal agar (Difco, Detroit, MI.), 2 g/L anhydrous glucose (Mallinckrodt, Paris, KY), 3 g/L sucrose (J.T. Baker, Phillipsburg, N.J.) and 1 g/L yeast extract (Difco, Detroit, MI.) according to the recipe of Spletzer and Enyedi (1999) and V-8 agar, 20 g/L agar (J.T. Baker, Phillipsburg, NJ), (175 ml/L V-8 juice (Campbell Soup Co., Camden, N.J.) 3 g/L $CaCO_3$, according to Simmons (1993). The fungus was grown at 25 $\pm$ 1°-C (Douglas, 1972) with a 12-hr photo period for 5-7 days. To induce sporulation, mycelia were subcultured on fresh MCMA (Spletzer and Enyedi, 1999). After 5-7 days the culture was scarified (Simmons and Roberts, 1993) and the plate was inverted and placed in a plastic box (Pioneer Plastics Inc., Dixon, KY) one cm above the surface to promote aeration and induce stress (Dr. K. Ivors, personal communication) and left for 24 hr. When needed a beaker containing a desiccant ($CaSO_4$) (W.A. Hammond Drierite Co., Xenia, OH) was placed in the box to absorb excess moisture

To make a spore suspension, spores were collected by misting sterile distilled water onto the culture. Spores were caught in a 500 ml beaker and suspended with a

surfactant, Tween 20 (Fisher Scientific, Fairlawn, NJ) per 60 ml aqueous spore solution. Spores were quantified by placing 10 µl of the spore suspension on a hemacytometer (Neubauer DHC-N01-2, SKC, Korea). An average spore count was taken based on the total of four quadrants and that number was multiplied by 10^4 to determine spore concentration. A spore suspension containing 5,000spores/ml was then transferred to a 60-ml fine mist pump spray bottle, which was used to inoculate one compound leaf of one tomato plant in the middle of the bed of each treatment replicate. This inoculation with *A. tomatophila* was done following the fifth spray treatment on the 10th of July. Each inoculated compound leaf was flagged for identification. Overhead sprinkler watering in the evening was done twice during the first two weeks to enhance fungal growth. Overhead watering was scheduled as needed throughout the trial. Approximately 10.16 cm of bark and leaf mulch (City of Clemson, SC) was applied over the plant beds; plastic mulch was not used in the 2007 trial. Data collection and statistical analysis were done as in the 2006 trial. Linear contrasting of all grouped treatment mean values was calculated. Linear correlation was calculated between yield and disease severity.

Greenhouse Trial

Tomato seeds (cv. 'Cherokee Purple'; Terra Organics LLC., Maxwell, CA) differed from that of the field trial seed due to availability were planted in potting mix. (Fafard 3B, Conrad Fafard Inc., Agawam, MA) inside 36-cell flats and grown in a greenhouse at Clemson University. After 6-8 wk of growth tomato plants were transplanted into 10.16 cm pots. Treatments included a water control, compost tea (CT), Serenade Max, Sonata, CT + Serenade Max, CT + Sonata. All treatments were applied

once to the plants until runoff using a pump sprayer 24 hr before pathogen inoculation. A 10,000 spores/ml suspension was made using spores harvested from *A. tomatophila* cultures on fresh MCMA (see field experiment methods above). A fine mist spray pump was used to apply 2 ml of the spore suspension on to each plant.

Ten replicate plants per treatment were placed in random order inside a mist chamber. The mist chamber measured 1.3 m x 1.3 m to accommodate the sixty plants and was constructed of wood for the frame and covered with clear plastic sheeting for the sides It was equipped with a small humidifier (Ultrasonic H-0565-0, ReliOn®); relative humidity was maintained above 60% throughout the experiment. Nightly water misting was done for the first two weeks to promote fungal growth. Watering was scheduled as needed. The percentage foliage of each plant with disease symptoms was assessed every 5 days using the percent rating scale (Table I). Disease ratings took into account compound leaves that appeared to have senesced due to disease. Statistical analysis was done as in the field experiments described above. Linear contrasts of treatments alone vs. treatments in combination were calculated.

Germination Assay

An *in vitro* assay was designed to assess the effect of biological disease control treatments on *A. tomatophila* spore germination. The treatments included municipal (chlorinated) water, sterile distilled water, compost tea (CT), Serenade, Sonata, CT + Serenade Max and CT + Sonata. Approximately 2 ml of each treatment solution were applied by a pump spray bottle directly to Petri dishes containing 2% water agar (20 g agar (Difco)/1 L distilled water). The seven treatments were randomized with five

replications and Petri dishes randomly numbered to avoid sampling bias. As in the greenhouse trials treatments were applied 24 hr before pathogen inoculation. After treatment each of the 35 plates were inoculated with 1 ml of *A. tomatophila* spore suspension (3000spores/ml).

Approximately 1 hr after inoculation each plate was evaluated with a dissecting microscope (Wild M5-22942, Heerburgg, Switzerland) at 50x magnification, aided by a circular grid (0.16 cm each square) in an effort to avoid replication of counts. For each plate 50 spores were evaluated for germination, which was designated germinated or not germinated. The germination assessment included the entire spore body and mycelial growth of the projecting spore beak. A second evaluation was done after 24 hr. The entire germination assay and evaluations after 1hr and after 24hr were repeated to measure reproducibility of results. Statistical analysis was done as indicated above.

CHAPTER III

RESULTS AND DISSCUSSION

Field Trial 2006

The low overall incidence of foliar disease during the 2006 field trial was associated with below-average rainfall during the trial period June 18th through October 12th (Weather Underground.com, 2006). Biotic pressure throughout the field from bacterial wilt caused by soil borne pathogen *Ralstonia solanacearum* contributed to the loss of sixty-two percent of the field tomato plants throughout the growing season. Foliar disease symptoms of gray leaf spot caused by the fungal pathogen *Stemphylium solani* were observed late in the season toward the end of the harvest period. On October 12th the average percentage of plants with disease symptoms ranged from 13.7% (2.73 disease rating) in the compost tea + Serenade Max™ treatment to 19.0% (3.79 disease rating) in the water control (Table 2, Fig. 1). The severity of disease was numerically higher in the water control than in the compost tea and Serenade treatments, but there were no statistically significant differences were observed in disease ratings among treatments (ANOVA) ($\alpha = 0.05$). Linear contrasting of all group treatment means was calculated and no significant differences were observed between the compared treatments ($\alpha=0.05$).Lower average disease severity found in the 5-day opposed to 10-day scheduled spraying of compost tea alone may have had an effect on inducing systemic acquired resistance of the plant's natural defenses (Zhang, et al., 1998). Although not significantly different the 5-day spraying showed a severity percentage of 15.6% (disease rating 3.12) opposed to the 10-day compost tea alone at 18.85%. Tandem use of compost tea + Serenade Max showed the lowest average with in each respective spraying schedule. The

use of biological fungicides such as Serenade Max and Sonata in tandem with conventional chemical fungicides has been shown to further enhance the suppressive efficacy on early blight (Zitter, et al, 2006.). Tomato yields were not determined in the 2006 trial.

Table 2. Gray leaf spot disease ratings in biological disease control treatments on 'Cherokee Purple' tomato, 2006 field trial.		
5-Day Spray Schedule	*Treatment*	*Average Disease Rating*
	Water	3.79 ± 0.50
	Compost Tea	3.12 ± 0.38
	Serenade Max	3.35 ± 0.46
	Compost Tea + Serenade Max	3.13 ± 0.51
	Compost Tea/Serenade Max Alternated	3.19 ± 0.38
10-Day Spray Schedule	Serenade Max	2.78 ± 0.37
	Compost Tea	3.77 ± 0.39
	Compost Tea + Serenade Max	2.73 ± 0.42

Table 2. Average disease rating values (refer to Table 1). N = 4. Individual observations per treatment plot ranged from N =12-19. Treatment rating values not significantly different (ANOVA and LSD test; $\alpha = 0.05$).

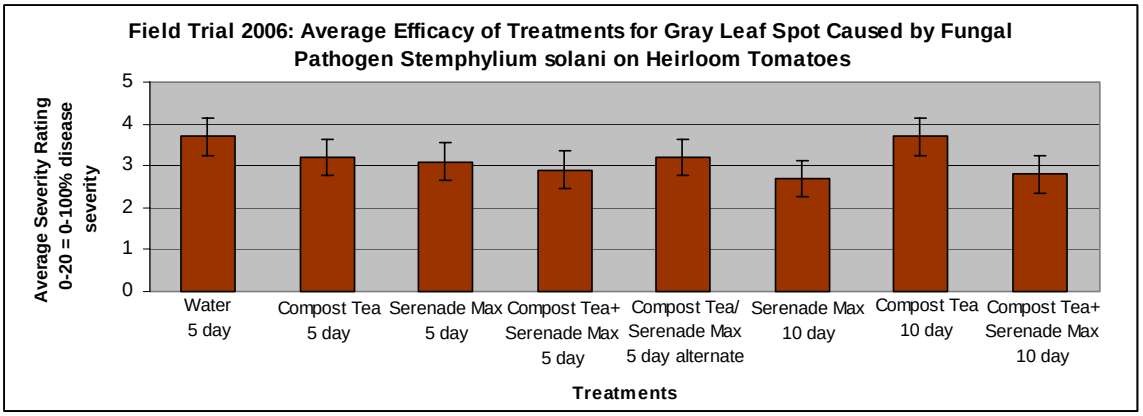

Figure 1. Average disease rating values (refer to Table 1). N = 12-19 per replication. Individual observations per treatment plot ranged from N =12-19 .Treatment rating values not significantly different (ANOVA and LSD test; $\alpha = 0.05$).
Lines above the bars represent standard deviation.

Field Trial 2007

June 28 was the first evaluation date that a low percentage of plants showed leaf spot symptoms on foliage. The pathogens were identified as *Alternaria alternata* and *A. tenuissima,* ubiquitous fungi that cause leaf spot symptoms on a wide range of host plants (Rotem, 1998).Because of the low incidence of fungal disease in 2006, in the 2007 trial, select plants (see Methods) were inoculated with *Alternaria tomatophila,* causal agent of tomato early blight. Inoculation was assumed to be successful based on the observation of foliar lesions symptomatic of early blight on inoculated leaves after approximately one week.

Early blight disease progressed over time with a dramatic increase on 8 Aug from the previous evaluation on 3 Aug but the treatments showed no statistically significant difference. On this date the average percentage of plants showing early blight symptoms ranged from 24.5% (disease rating of 4.9) in the compost tea alone treatment to 42.5% (disease rating of 8.5) in the treatment where compost tea was alternated with Sonata™ (Fig. 2, Table 3). On subsequent sample dates disease severity remained lower in the compost tea alone treatment and in some of the other treatments compared with the water control, but differences were not statistically significant (α=0.05, Table 3). Similarly, no statistically significant differences among treatments when disease rating values were combined over all sample dates (α=0.05, Table 4, Fig. 3). Likewise, a linear contrast of treatment group means was calculated and showed no significant difference (α=0.05).

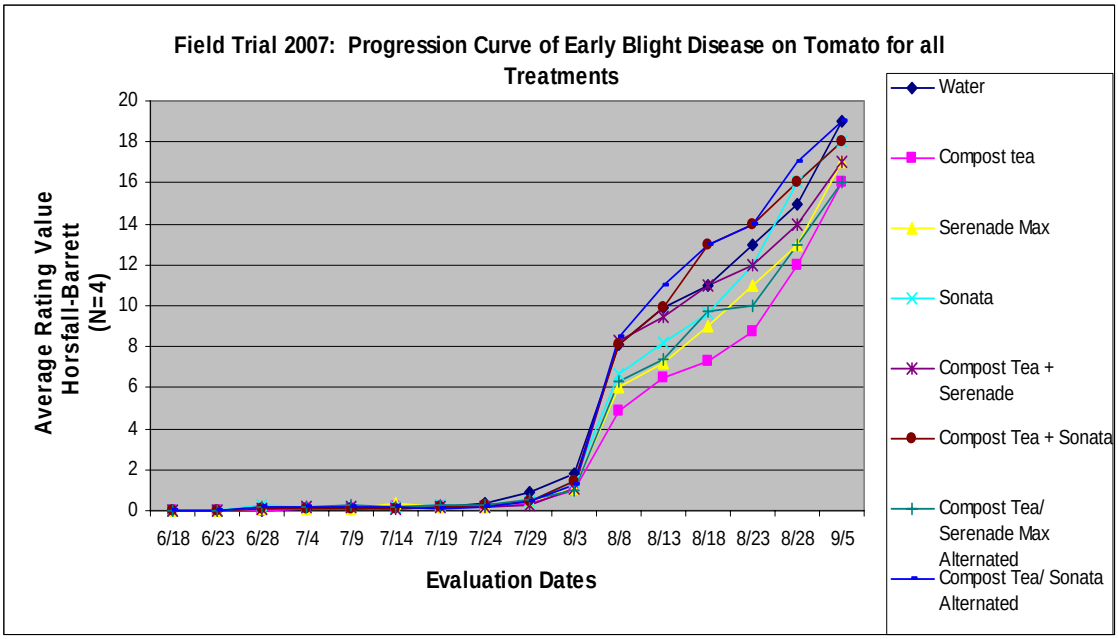

Figure 2. Progression of early blight disease in biological control treatments on 'Cherokee Purple' tomato. Average disease rating values (refer to Table 1); N= 4

Table 3. **Weekly mean disease ratings in biological disease control treatments on 'Cherokee Purple' tomato, 2007 field trial. (N=4).**

Treatment	18-Jun	23-Jun	28-Jun	4-Jul	9-Jul	14-Jul	19-Jul	24-Jul
Water	0	0	0	0.08 ± 0.08a	0.08 ± 0.06b	0.14 ± 0.09a	0.19 ± 0.07a	0.33 ± -0.09a
CT	0	0	0.03 ± 0.6a	0.06 ± 0.08a	0.11 ± 0.06ab	0.22 ± 0.09a	0.17 ± 0.07a	0.22 ± -0.09a
Ser	0	0	0.11 ± 0.6a	0.11 ± 0.08a	0.06 ± 0.06ab	0.33 ± 0.09a	0.14 ± 0.07a	0.19 ± 0.09a
Son	0	0	0.3 ± 0.6a	0.14 ± 0.08a	0.14 ± 0.06ab	0.14 ± 0.09a	0.25 ± 0.07a	0.22 ± 0.09a
CT+Ser	0	0	0.08 ± 0.6a	0.19 ± 0.08a	0.17 ± 0.6ab	0.11 ± 0.09a	0.17 ± 0.07a	0.17 ± 0.09a
CT+Son	0	0	0.05 ± 0.6a	0.08 ± 0.08a	0.11 ± 0.06b	0.11 ± 0.09a	0.19 ± 0.07a	0.25 ± 0.09a
CT/Ser alt	0	0	0.14 ± 0.6a	0.19 ± 0.08a	0.28 ± 0.06b	0.19 ± 0.09a	0.25 ± 0.07a	0.25 ± 0.09a
CT/Son alt	0	0	0.17 ± 0.6a	0.14 ± 0.08a	0.17 ± 0.06ab	0.17 ± 0.09a	0.11 ± 0.07a	0.14 ± 0.09a

Treatment	29-Jul	3-Aug	8-Aug	13-Aug	18-Aug	23-Aug	28-Aug	5-Sep
Water	0.92 ± 0.17a	1.8 ± 0.25a	8.10 ± 1.6a	9.90 ± 2.0a	11.18 ± 2.3a	12.58 ± 2.3a	15.39 ± 1.7ab	18.72 ± 1.3a
CT	0.39 ± 0.17b	1.0 ± 0.25b	4.90 ± 1.6a	6.47 ± 2.0a	7.31 ± 2.3a	8.70 ± 2.3a	11.64 ± 1.7b	16.22 ± 1.3a
Ser	0.44 ± 0.17ab	1.1 ± 0.25ab	6.00 ± 1.6a	7.20 ± 2.0a	9.03 ± 2.3a	10.75 ± 2.3a	13.47 ± 1.7ab	16.97 ± 1.3a
Son	0.44 ± 0.17ab	1.4 ± 0.25ab	6.70 ± 1.6a	8.22 ± 2.0a	9.61 ± 2.3a	11.97 ± 2.3a	15.97 ± 1.7ab	18.28 ± 1.3a
CT+ Ser	0.28 ± 0.17ab	1.1 ± 0.25b	8.30 ± 1.6a	9.53 ± 2.0a	10.53 ± 2.3a	11.94 ± 2.3a	14.22 ± 1.7ab	17.00 ± 1.3a
CT+ Son	0.47 ± 0.17ab	1.4 ± 0.25ab	8.10 ± 1.6a	9.94 ± 2.0a	12.60 ± 2.3a	14.25 ± 2.3a	16.42 ± 1.7ab	18.03 ± 1.3a
CT/Ser alt	0.56 ± 0.17ab	1.0 ± 0.25b	6.30 ± 1.6a	7.42 ± 2.0a	9.70 ± 2.3a	10.61 ± 2.3a	13.47 ± 1.7ab	16.42 ± 1.3a
CT/Son alt	0.41 ± 0.17ab	1.3 ± 0.25ab	8.50 ± 1.6a	10.75 ± 2.0a	12.50 ± 2.3a	14.33 ± 2.3a	16.75 ± 1.7a	19.06 ± 1.3a

Table 3. Average disease rating values (refer to Table 1). Treatment rating values not significantly different (ANOVA and LSD test; $\alpha = 0.05$).
Treatments: Water, compost tea (CT), Serenade Max (Ser), Sonata (Son), compost tea + Serenade Max (CT+ Ser), compost tea + Sonata (CT+ Son), compost tea alternated each spray date with Serenade Max (CT/Ser alt), compost tea alternated each spray date with Sonata (CT/Son alt).

Table 4. Mean early blight disease ratings over all sample dates on 'Cherokee Purple' tomato (N = 64), 2007 field trial.	
Treatment	*Average Value*
Water	4.96 ± 0.69
Compost Tea	3.59 ± 0.69
Serenade Max	4.12 ± 0.69
Sonata	4.60 ± 0.69
Compost Tea + Serenade Max	4.61 ± 0.69
Compost Tea + Sonata	5.12 ± 0.69
Compost Tea/Serenade Max Alternated	4.18 ± 0.69
Compost Tea/Sonata Alternated	5.28 ± 0.69

Table 4. Average disease rating values (refer to Table 1). Disease rating values were not significantly different among treatments (ANOVA and LSD test; $\alpha = 0.05$).

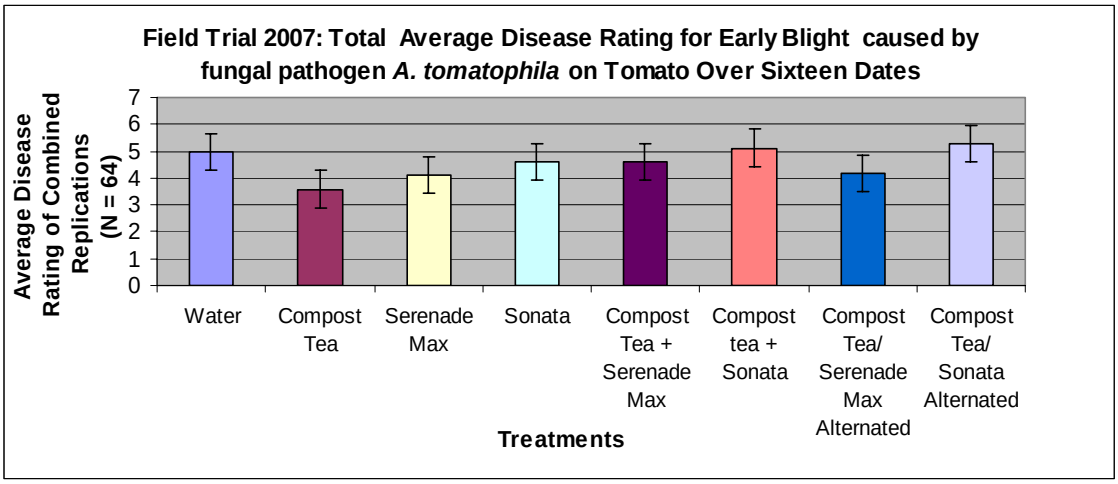

Figure 3. Average disease rating values (refer to Table 1). Disease rating values were not significantly different among treatments (ANOVA and LSD test; $\alpha = 0.05$).
Lines above the bars represent the standard deviation.

In addition to early blight disease due to inoculations, some plants were naturally infected with what was verified as tomato spotted wilt virus (TSWV). TSW continued to

spread on tomato throughout the experimental field; infected plants were not removed to maintain a consistent sample number for visual symptom ratings. It was possible to discriminate symptoms of early blight from TSW symptoms through the 18 Aug. sample date. Beginning with the 23 Aug. sample it became difficult to distinguish plants with fungal disease from plants with TSW symptoms, thus subsequent symptom ratings at the mid-upper range of the rating scale were based on infection from both lesions symptomatic of *A. tomatophila* and TSWV. This greatly influenced the severity rating and efficacy potential of the treatments.

Yields of marketable tomatoes were measured beginning with the first harvest on 8 Aug. and subsequently on 5 day intervals through 23 Aug. when disease was ubiquitous throughout the field (Fig. 2, Table 3) and yields began to decline (Table 5). In Fig. 4, a general negative relationship among treatments between the magnitude of the disease rating and yield was observed ($P<0.05$). Harvest yields when compared in biological treatments have been known to be highly variable (Wzelaki, et al., 2004). Variability may have been observed if yield weight was averaged over the entire harvest rather than at the peak. Correlation between yield and disease severity showed poor prediction of the linear trend ($R^2=0.61$). However, the inverse relationship between the average disease rating and yield in the 2007 field trial showed the average marketable weight of fruit treated with compost tea (4.80lbs) and Serenade Max (3.85lbs) producing significantly higher yields($\alpha= 0.05$) than the other treatments where Sonata (1.56lbs) was applied alone, in treatments where compost tea was combined with Serenade Max (1.50lbs) and Sonata (1.15lbs), and in the treatments where compost tea applications were alternated with Serenade Max (1.75lbs) and Sonata (1.91lbs (Table 5). The compost tea samples

submitted for analyses did contain plant potential nitrogen (Tables 6, 7) based on total protozoan inoculum, but due to the low microbial count specifically the active bacterial and fungal biomass it is doubtful that runoff from the foliar compost tea application had provided a significant supplemental source of nitrogen. It has been suggested for organic market fresh tomato production that 75-100lbs of nitrogen per acre is required (Diver, et al., 1999). The two compost tea analysis described below estimated a potential of 5 and 200 lbs per acre respectively but according to a source at Soil Food Web (personal communication) the actual nitrogen content would be significantly lower.

Table 5. Overall average yields (lbs. averaged over four evaluation dates) of marketable 'Cherokee Purple' tomatoes on four harvest dates (N=16), 2007 field trial.

Water	1.83±0.72bc
Compost tea	4.80±0.72a
Serenade Max	3.86±0.72ab
Sonata	1.56±0.72c
Compost Tea + Serenade Max	1.50±0.72c
Compost Tea + Sonata	1.15±0.72c
Compost Tea/ Serenade Max Alternated	1.75±0.72c
Compost Tea/ Sonata Alternated	1.91±0.72bc

Table 5. Means within columns sharing the same letter are not significantly different (ANOVA and LSD test; $\alpha = 0.05$).

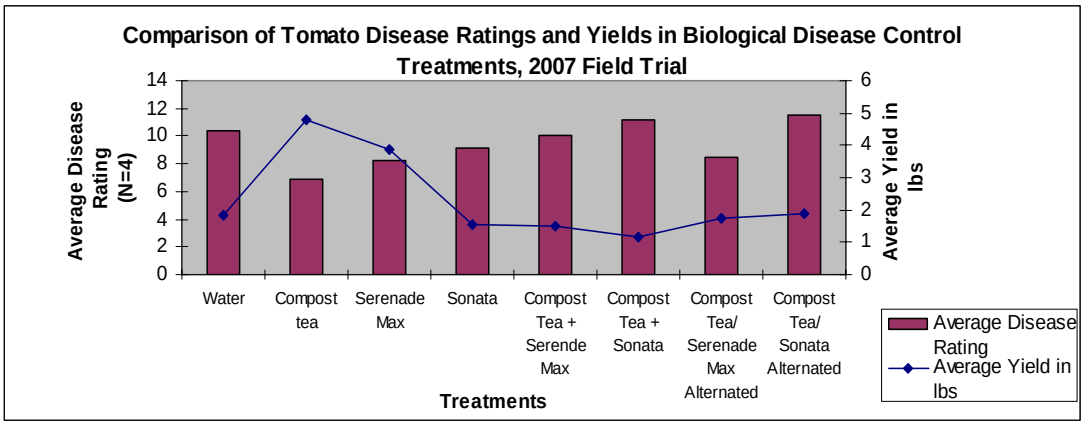

Figure 4. Bars represent disease ratings averaged over 4 sample dates. Line represents average marketable yields over 4 sample dates.

Compost Tea Analysis

Analysis of two batches of compost tea was performed on two batches of compost tea by the New York Soil Food Web Laboratory (www.soilfoodweb.com). The first sample was taken midway through the 2007 field experiment on 9 Aug. and the second sample at the end of the experiment on 14 Sep. (Tables 5 and 6). The analyses provide an estimate of active and total bacteria, fungi, nematodes and other microbes, but do not identify specific microbial species. For application of compost tea in plant disease control the microbial populations in the compost must be increased during the production or brewing process (Sheuerell and Mahaffee, 2004). Both analyses indicated that the numbers of active bacteria and fungi were in the range considered 'low'. However the number of total bacteria and fungi in the first analysis showed good bacterial content but low fungal content (Table 6) and the second analysis (Table 7) both were considered 'good' based on the Soil Food Web analysis. As it has been seen in other compost tea biofungicidal evaluations, analysis of the tea showed that it was largely bacterial and more fungal activity may be needed to suppress fungal diseases of tomato (McGrath and

Moyer, 2003). The primary reason for producing compost tea is to transfer microbial biomass, fine particulate organic matter and soluble chemicals components of compost into an aqueous phase that can be applied to the plant surfaces (NOSB, 2004). A number of factors inherent in the brewing and extraction process may affect microbial population density, including removal of microbes attached to compost material during the straining (Bess, 2000). Moreover, environmental conditions such as water pollution or chlorinated water found in municipal water sources could have negatively impacted microbial populations in the composted extract. The difference in nitrogen availability may be due to the higher estimate of flagellates and amoeba in the second analysis (Table 7).The fluctuation of potential nitrogen levels between the two analyses is associated with overall protozoan inoculum. Mobilization of nitrogen has been associated with changes in population density of microorganisms and soil fauna, seasonally changing abiotic factors and management, such as fertilization, harvesting and addition of harvest residues to the soil (Verhoef and Brussaard, 1990).

Table 6. Soil Food Web analysis of compost tea sample on 9 Aug., 2007. 8/9/2007

Organism Biomass data		Tea Volume (ml)	Active Bacteria (µg/ml)	Total Bacteria (µg/ml)	Active Fungal (µg/ml)	Total Fungal (µg/ml)	Hyphal Diameter (µm)
Result		1	1.92	333	0	0.13	2.25
Comments			Low	Good	Low	Low	
Expected	Low		10	150	2	2	
Range	High		150	3000	10	20	

Organism Biomass data		Flagellates #/g	Amoebae #/g	Ciliates #/g	Total Nematodes #/ml		Plant Available N Supply lbs/acre
Result		460	4	4	lbs/acre		5+
Comments		Low	Low	Low	Low		
Expected	Low	1000	1000	20	2		
Range	High			50	10		

Organism Biomass data		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Bacterial to Active Bacterial
Result		0.0004	0	0.006	0
Comments		Low	Low	Low	Low
Expected	Low	0.01	0.1	0.1	0.9
Range	High	0.1	0.25	0.25	1.1

Table 6. First analysis of compost tea.

Table 7. Soil Food Web analysis of compost tea sample on 14 Sept., 2007.

Organism Biomass data		Tea Volume (ml)	Active Bacteria (µg/ml)	Total Bacteria (µg/ml)	Active Fungal (µg/ml)	Total Fungal (µg/ml)	Hyphal Diameter (µm)
Result		1	4.48	197	1.22	4.87	2.25
Comments			Low	Good	Low	Good	
Expected	Low		10	150	2	2	
Range	High		150	3000	10	20	

Organism Biomass data		Flagellates #/g	Amoebae #/g	Ciliates #/g	Total Nematodes #/ml	Plant Available N Supply lbs/acre
Result		1386	46	5	0.04	200+
Comments		High	Low	Low	Low	
Expected	Low	1000	1000	20	2	
Range	High			50	10	

Organism Biomass data		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Bacterial to Active Bacterial
Result		0.02	0.25	0.02	0.27
Comments		Good	Good	Low	Low
Expected	Low	0.01	0.1	0.1	0.9
Range	High	0.1	0.25	0.25	1.1

Table 7. Second analysis of compost tea.

Greenhouse Trial 2007

In the greenhouse trial biological disease control treatments were sprayed onto test plants prior to inoculation with *A. tomatophila*. This was done based on manufacturer recommendations to use the biological treatments preventatively before infection occurs and when conditions are conducive to disease development (AgraQuest, product application instructions). Lesions characteristic of *A. tomatophila* infection were visible on inoculated leaves 5-7 days after inoculation. Figure 5 shows the progression of disease symptoms over time. Differences in disease ratings among treatments became apparent on the third sample date, 10 days after inoculation, and continued throughout the trial.

Analysis of disease ratings combined over all sample dates indicated that the percentage of foliage with disease symptoms was significantly lower in all of the biological disease control treatments compared with water control 26.15% (disease rating of 5.23) (Table 8, Fig. 6). Among the biological control treatments, Serenade Max13.15% (disease rating 2.63), compost tea + Serenade12.5% (disease rating of 2.50), and compost tea + Sonata14.3% (disease rating of 2.86) were statistically significant compared with compost tea19.95% (disease rating of 3.99) alone. Linear contrasting of treatment groups confirmed compost tea in combination with the biological fungicides was significantly different (α=0.05) than the treatments alone. The greenhouse allowed greater control of environmental pressures that were naturally found in the field trials specifically lack of adequate moisture needed for fungal development (Zitter et al., 2005). In the greenhouse nightly misting provided the moisture needed for fungal growth and the pump sprayer provided even coverage of the treatments over the entire leaf surface. Lack of moisture and inability to achieve total plant coverage of the treatments are important factors that

contributed to the variability in the field. In the greenhouse, each treatment replicate could be individually sprayed to run off giving maximum coverage of biologically active content to the entire plant surface. In the field trials wind drift and the size of the mature tomato plants made total coverage of the biological treatments difficult to achieve as older lower leaves are more susceptible (Vloutoglou and Kalogerakis, 2000) to *A. tomatophila* infection were covered beneath the undergrowth of the lateral and newly forming apical leaves.

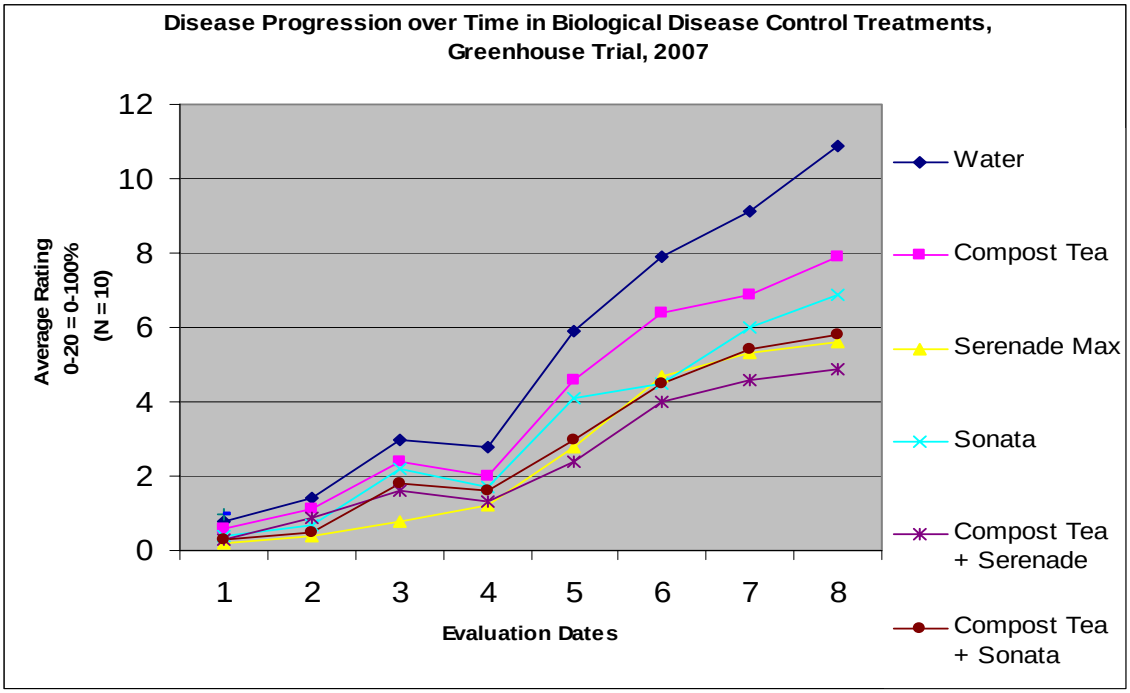

Fig.5. Average disease rating values taken over 8 sample dates at 5-day intervals. Disease ratings represent proportion of diseased foliage per plant (Table 1, N=10).

Treatments	Disease ratings averaged over all sample dates, greenhouse trial, 2007 (N=80)
Water	$5.23^{\pm 0.35}$a
Compost Tea	$3.99^{\pm 0.35}$b
Serenade Max	$2.63^{\pm 0.35}$c
Sonata	$3.46^{\pm 0.35}$bc
Compost Tea + Serenade Max	$2.50^{\pm 0.35}$c
Compost Tea + Sonata	$2.86^{\pm 0.35}$c

Table 8. Average disease rating values taken over 8 sample dates at 5-day intervals. Disease ratings represent proportion of diseased foliage per plant (Table 1). Means with the same letter are not significantly different (ANOVA and LSD test; (α= 0.05).

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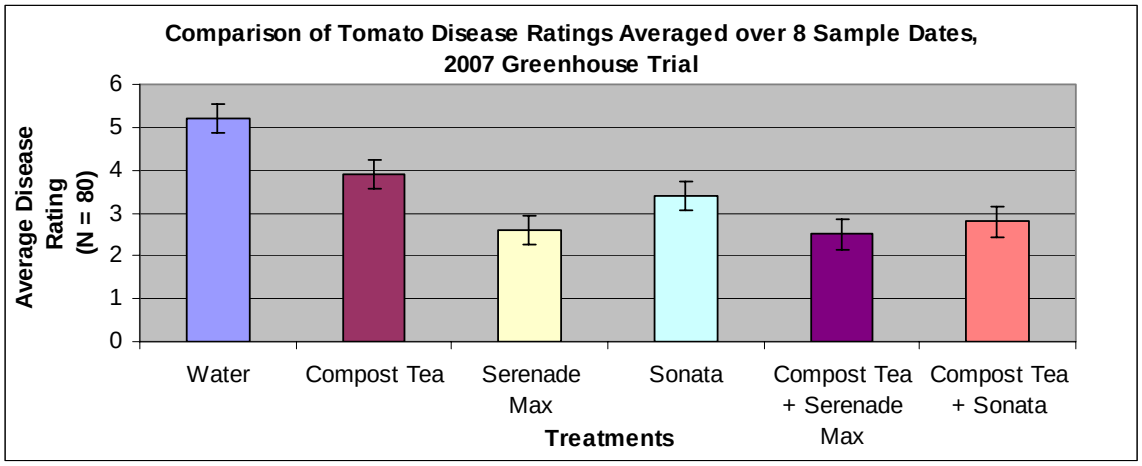

Figure 6. Average disease rating values taken over 8 sample dates at 5-day intervals Disease ratings represent proportion of diseased foliage per plant (Table 1). Lines above the bars represent standard deviation.

Table 9 lists average disease rating values by sample date. Beginning with the 3 Aug. sample date when the average percentage of plant foliage showing symptoms of the disease in the water control increased to 15%, and on all subsequent dates, disease ratings in the Serenade Max, compost tea + Serenade Max, and compost tea + Sonata treatments

remained significantly lower than in the water control. The overall lower average severity ratings of the combined treatments showed no significant difference between Serenade Max and Sonata alone but that the addition of compost tea adding organic particulate matter or the addition of microbial populations may have added to the suppressive activity of the commercial biofungicides and subsequent lower average ratings than the biofungicides alone (Tables 8, 9). Statistical analysis using linear contrasting between treatments alone vs. treatments combined showed combined treatments different than treatments alone (α=0.05). However, tandem use of Serenade and Sonata has been shown to have significantly higher foliar disease (EB) on tomato compared to biological fungicides alone or treatments alternated (Wszelaki et al., 2003). Furthermore, Serenade Max and Sonata combined with conventional chemical fungicides have proven to be effective in one growing season although not effective the following year as an increase of EB severity has been reported (Zitter et al., 2005). It would be in error to assume combined treatments is a panacea for fungal pathogenicity however the result of the greenhouse study suggests a biological effectiveness against EB occurred.

Table 9. Average disease ratings by sample date, 2007 greenhouse trial (N=10)

Treatments	24-Jul	29-Jul	3-Aug	8-Aug
Water	$0.80^{\pm 0.13}$a	$1.40^{\pm 0.24}$a	$3.0^{\pm 0.36}$a	$2.80^{\pm 0.36}$a
Compost Tea	$0.60^{\pm 0.13}$ab	$1.10^{\pm 0.24}$ab	$2.4^{\pm 0.36}$ab	$2.00^{\pm 0.36}$ab
Serenade Max	$0.20^{\pm 0.13}$c	$0.40^{\pm 0.24}$c	$0.80^{\pm 0.36}$c	$1.20^{\pm 0.36}$b
Sonata	$0.40^{\pm 0.13}$bc	$0.70^{\pm 0.244}$bc	$2.20^{\pm 0.36}$ab	$1.70^{\pm 0.36}$b
Compost Tea + Serenade Max	$0.30^{\pm 0.13}$bc	$0.90^{\pm 0.24}$abc	$1.60^{\pm 0.36}$bc	$1.30^{\pm 0.36}$b
Compost Tea + Sonata	$0.30^{\pm 0.13}$bc	$0.50^{\pm 0.24}$bc	$1.80^{\pm 0.36}$bc	$1.60^{\pm 0.36}$b

Treatments	13-Aug	18-Aug	23-Aug	28-Aug
Water	$5.90^{\pm 0.54}$a	$7.90^{\pm 0.63}$a	$9.10^{\pm 0.72}$a	$10.90^{\pm 0.77}$a
Compost Tea	$4.60^{\pm 0.54}$ab	$6.40^{\pm 0.54}$ab	$6.90^{\pm 0.72}$b	$7.90^{\pm 0.77}$b
Serenade Max	$2.80^{\pm 0.54}$cd	$4.70^{\pm 0.54}$bc	$5.30^{\pm 0.72}$bc	$5.60^{\pm 0.77}$c
Sonata	$4.10^{\pm 0.54}$bc	$4.50^{\pm 0.54}$bc	$6.00^{\pm 0.72}$bc	$6.90^{\pm 0.77}$bc
Compost Tea + Serenade Max	$2.40^{\pm 0.54}$d	$4.00^{\pm 0.54}$c	$4.60^{\pm 0.72}$c	$4.90^{\pm 0.77}$c
Compost Tea + Sonata	$3.00^{\pm 0.54}$cd	$4.50^{\pm 0.54}$c	$5.40^{\pm 0.72}$bc	$5.80^{\pm 0.77}$bc

Table 9. Average disease rating values by sample date. Disease ratings represent proportion of diseased foliage per plant (Table 1). Means within columns sharing the same letter are not significantly different (ANOVA and LSD test; α= 0.05).

Spore Germination Assay

A germination assay was conducted to evaluate the effect of the biological control treatments on germination of *A. tomatophila* spores. In Trial A the first of two trials, the pathogen was sprayed onto 2% water agar at a concentration of 5000spores/ml. After 1 hr after inoculation, the compost tea alone, compost tea + Serenade Max, compost tea + Sonata, and Serenade Max alone treatments all had germination rates significantly lower than the two water controls (Table 10). Serenade Max alone had the greatest effect on suppressing germination after 1 hr with a germination average of 9%. At twenty four hours only the Serenade Max + compost tea and Serenade Max alone treatments had significantly lower germination rates than the water controls (Table 10). Serenade Max alone had the lowest 24h germination rate at 20%, significantly lower than all other biological control treatments.

In the Trial B assay the *A. tomatophila* spore inoculation concentration was 3000 spores/milliliter. Trends in spore germination among treatments were similar to those in the first trial. At 1 hr after inoculation germination was significantly lower in all biological disease control treatments compared with the water controls (Table 11). Compost tea + Serenade Max, compost tea + Sonata, and Serenade Max alone had significantly lower germination rates than all other treatments. At 24 hr these same treatments continued to significantly reduce germination compared to other treatments, with lowest germination rates in the Serenade Max alone treatment (9%). Compost tea has been reported to be effective *in vitro* for the suppression of conidia that cause EB (Haggag, 2007). Although suppression of conidia did occur after1hr results of the

germination assay showed that after 24 hr compost tea was ineffective (94% germination) in both reproduced trials.

Figures 7 and 8 show a graphical comparison of treatment germination rates in the two trials. Greater variability in observed germination between trials at 1 hr is most likely because plates were examined randomly in sequence and by necessity some plates were counted sooner than others. Peak germination at or near 100% was observed at 24 hr in the water control treatments and in the Sonata alone and compost tea alone treatments (Fig. 8). The compost tea + Serenade Max, compost tea + Sonata, and Serenade Max alone treatments resulted in a greater suppression of conidial germination over time (Fig. 8). Evidence that compost tea combined with biofungicides provided superior suppression of germination than compost tea alone was also reported by McGrath, (2004). It may have been due to the presence of supplemental microbes in the compost tea that surround germinating conidia while the biofungicides destroy fungal cell walls (Elmer and Reglinsk, 2006). However, after 24 hr compost tea + Sonata was not significantly different in trial A than the water controls, compost tea alone or Sonata alone. This may be due to the inherent variability of performance of Sonata as seen in many biological fungicides (Wzelaki, et al., 2003, Wzelaki et al. 2004, McGrath and Moyer, 2004). After 24 hr the microorganisms in the compost tea alone may have become ineffective as evident in the data and the tea analyses, possibly due to lack of available food as the brewing process may necessitate longer steeping time of the supplemental food additives or greater oxygenation pressure form the aeration device.

Table 10. Spore Germination Trial A: Average proportion of germinated *A. tomatophila* spores per treatment on water agar at 1 and 24 hours after inoculation. (N=5).

Treatment	1 hour	24 hours
Water, Sterile Distilled	$0.85^{\pm 0.05}a$	$1.00^{\pm 0.06}a$
Water, Municipal	$0.47^{\pm 0.05}b$	$0.98^{\pm 0.06}a$
Sonata	$0.36^{\pm 0.05}bc$	$0.98^{\pm 0.06}a$
Compost Tea	$0.30^{\pm 0.05}cd$	$0.95^{\pm 0.06}a$
Compost Tea + Serenade Max	$0.22^{\pm 0.05}de$	$0.56^{\pm 0.06}b$
Compost Tea + Sonata	$0.18^{\pm 0.05}de$	$0.84^{\pm 0.06}a$
Serenade Max	$0.09^{\pm 0.05}e$	$0.20^{\pm 0.06}c$

Table 10. Means within columns sharing the same letter are not significantly different (ANOVA and LSD test; $\alpha = 0.05$).

Table 11. Spore Germination Trial B: Average proportion of germinated *A. tomatophila* spores per treatment on water agar at 1 and 24 hours after inoculation. (N=5).

Treatment	1 hour	24 hours
Water, Sterile Distilled	$1.0^{\pm 0.09}a$	$0.99^{\pm 0.05}a$
Water, Municipal	$0.86^{\pm 0.09}a$	$0.98^{\pm 0.05}a$
Sonata	$0.49^{\pm 0.09}b$	$0.98^{\pm 0.05}a$
Compost Tea	$0.54^{\pm 0.09}b$	$0.94^{\pm 0.05}a$
Compost Tea + Serenade Max	$0.10^{\pm 0.09}c$	$0.69^{\pm 0.05}b$
Compost Tea + Sonata	$0.17^{\pm 0.09}c$	$0.32^{\pm 0.05}c$
Serenade Max	$0.02^{\pm 0.09}c$	$0.09^{\pm 0.05}d$

Table 11. Means within columns sharing the same letter are not significantly different (ANOVA and LSD test; ($\alpha = 0.05$).

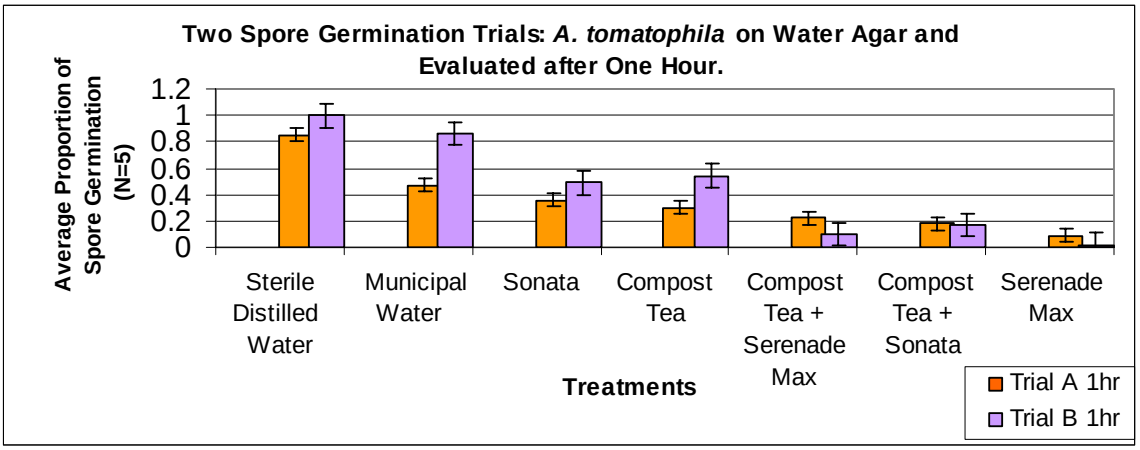

Figure 7. Comparison of Trial A and B treatment germination rates at 1 hr. 50 spores were counted per replication.

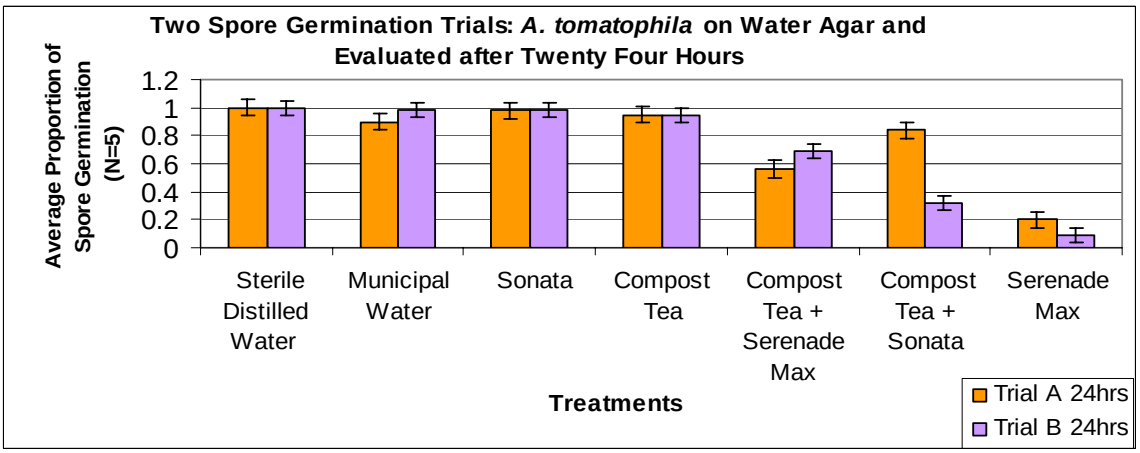

Figure 8. Comparison of Trial A and B treatment germination rates at 24 hr. 50 spores were counted per replication.

Municipal water used in the compost tea was dechlorinated prior to brewing process. However, the municipal water was not dechlorinated prior to mixing with the biofungicide treatments. Therefore the two water controls were included to determine the effect of residual chlorine in municipal water on spore germination. Germination rate at 1 hr was significantly lower in municipal water than in distilled water in Trial A, but

differences were not significant in Trial B. After 24hr germination was high for both water treatments. These results indicate that chlorine in municipal water may initially inhibit *A. tomatophila* spore germination but with variable effect.

CHAPTER IV

CONCLUSION

Control of plant disease is a major limiting factor in organic vegetable production, particularly in the south where warm, moist growing conditions are highly favorable for disease development. Nevertheless organic growers manage disease with variable success through a combination of cultural and biological methods, and are continually seeking more cost-effective strategies. Because compost can be produced cheaply on-farm it represents a potentially valuable disease management tool for small scale, limited resource farmers

The efficacy of compost tea for disease management in organic vegetable systems has been reported anecdotally, but scientific studies have been inclusive; i.e. some have demonstrated suppression of disease while others have shown no significant effect (Scheuerell and Mahaffee, 2002; Weltzein. 1991). Results of the field experiments reported here suggest that the compost tea used in the two-year study provided a low level of protection against early blight, but results were variable and not statistically significant compared to the water control and other biofungicide treatments. Furthermore, in the field experiments, combination with commercial biofungicides Serenade Max and Sonata did not appear to improve the effectiveness of compost tea. There are a myriad of possible factors that could contribute to the variability in the effectiveness of compost tea in the field including the raw materials used in the compost, the compost production process, the microbial food supplements used, compost tea application methods and timing, disease severity and environmental conditions (Scheuerell and Mahaffee, 2002; Weltzein, 1991, Al-Dahmani et al., 2003)

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