Tea Time
In the Tropics

A handbook for compost tea production and use.

Edited by
Theodore Radovich & Norman Arancon

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Editors

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Acknowledgement
The editors wish to acknowledge the innovative growers, early adopters and pioneering scientists who have advanced our understanding of compost tea.

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Introduction

Water-based extracts of compost (compost "tea") have long been recognized as potentially valuable in promoting plant growth. Recent innovations in production and application have popularized tea use among food producers, landscape managers and others interested in promoting plant health. This renewed interest in compost tea has made the input fairly controversial, and it is often presented as either a "Silver Bullet", or conversely, "Snake Oil." Like most other traditional agricultural inputs, compost tea is neither. Unfortunately, our ability to effectively employ compost teas to their full advantage is severely limited by our poor understanding of the interactions between compost type, crop and environmental factors as they relate to plant yield and quality, particularly under tropical conditions. These gaps in our knowledge limit the efficacy of compost tea applications on the farms that currently employ this strategy, and seriously restrict the extension and adoption of compost tea technology to conventional farms that want to improve the sustainability of their operations.

The purpose of this book is to critically evaluate the phenomenon of compost tea from three general perspectives: Growers, Researchers and Industry. By integrating these perspectives into a cumulative experience, we hope to improve our understanding of the potential and limitations of this technology from scientific, economic and practical points of view. The book is arranged to specifically address the varied needs of multiple stakeholder groups. **Individual chapters** are intended to provide both broad and in-depth summaries of the science and technology of compost tea, particularly from a tropical perspective. **Brew Master** insets feature innovators, long time users and recent adoptors of compost tea, who share their anecdotal experiences. Two longtime users describe their efforts to quantify the impacts of compost tea on their farms. **Frequently Asked Questions (FAQs)** are interspersed throughout the book and address common questions by people interested in using compost tea, including the important question "Does it work?

Chapter 1 - Compost Quality

Ted Radovich, Nguyen Hue and Archana Pant

It is a simple fact: you cannot have high quality compost tea without high quality compost. In other words, if you want to promote plant growth with compost tea the extract must be derived from compost that also promotes plant growth. Compost quality is determined by starting materials (feedstocks), as well as the management of moisture, temperature, other production factors and storage conditions. All of these factors influence the rate of biological decomposition and ultimately determine final compost quality. Publications on compost production are available from several sources elsewhere (Rynk and Richard, 2001; Sheldon et al., 2005). This chapter is intended to improve the compost tea practitioners awareness of indicators that are most commonly used to evaluate compost quality.

Maturity

Maturity is an important concept that is closely related to the quality of compost. Simply put, mature compost has decomposed enough to promote plant growth. Objective indicators of maturity have been established and are discussed below. Most of these indicators require special equipment or analysis fee, and it takes time for results to be received.

Experienced producers and users of compost often evaluate maturity using subjective indicators such as color, smell, and feel (Kuo et al. 2004; Sullivan and Miller, 2001). Dark brown, earthy smelling, moist, and finely divided composts that lack sour or ammonia off-odors are expected to be of adequate maturity to promote plant growth. However, more quantitative measures are required to better enable end-users to determine the optimal rate and frequency of compost application.

C:N Ratio The ratio of carbon to nitrogen in compost is probably the best known objective indicator of compost quality. Optimal C:N range is considered 10-20:1 since composts within this range are unlikely to immobilize, or "rob" plant available nitrogen. Typically, composts with C:N above 25:1 are unacceptable for use in cropping systems. It is important to note that C:N ratios are not adequate to use as the sole determinant of compost maturity. However, C:N ratios are extremely useful in prescreening compost for acceptable maturity. Compost that have C:N $< 25:1$ should be further evaluated for other indicators of compost maturity.

Stability A common measure of compost maturity is stability or the potential for compost to further decompose. The most common measure of compost stability are self heating tests where the maximum rise in temperature of moist compost are measured over a 5-10 day period. Excessive heating (>20 C increase in 10 days) indicates unstable compost (Briton, 2000).

Respiration or carbon dioxide evolution from moistened compost is also used as an indicator of stability. Respiration and self heating are both indicators of

Figure 1.1Compost quality is often described in terms of maturity; Mature compost promotes plant growth, while immature compost retards it. Phytotocicity resulting from immature compost may be due to high C:N, the precence of toxic compounds or other factors. In the photo above eggplant seedlings are growing in an immature thermophilc compost (left) and mature vermicompost (right). *Photo: Ted Radovich*

biological activity. Although biological activity is considered desirable in composts, unstable compost that rapidly consumes oxygen can result in anaerobic conditions after bagging, resulting in off-odors and the production of phytotoxic compounds. Unstable composts are also likely to be low in plant available nutrients.

Plant available nitrogen Nitrate and ammonium are important indicators of compost maturity (Briton, 2000; Sullivan and Miller, 2001). Nitrate concentration is recommended to be at least 100 ppm for mature compost. Some sources recommend that nitrate and other plant available nitrogen should not exceed 300 ppm when compost is being used as a substrate in growing medium. However, composts with nitrate concentrations of greater than 600-2000 ppm are associated with the best plant growth in greenhouse and field trials in Hawaii (Pant, 2011). Ammonium should be less than 1000 ppm and the ratio of ammonium to nitrate in the compost should be less than 1:1.

Other measures of maturity Other measures of maturity include EC (<2.0 mmo), pH (6.0-7.5). Compost quality is also indicated by the presence or absence of contaminants (Walker, 2001). Potential major contaminants include human pathogens, physical contaminants such as plastics, weed seeds, heavy metals, and pesticide residues. Maintaining high temperatures for a period of time during the composting process has been the primary approach towards minimizing contaminants particularly human pathogens. Screening is also recommended which generating and removes the bulk of physical contaminants.

Not all compost is created equal

Vermicompost -

Vermicompost is generated by worms and associated microorganisms. Vermicompost quality will vary depending on many factors including worm species, raw material used, and the age of the compost. Vermicomposts are generally of finer structure, contain more nutrients, and have higher microbial activity than other types of composts. High levels of nutrient levels and plant growth regulators make vermicompost ideal for compost tea production.

"Handcrafted" or "Artisan" thermophilic

Careful monitoring of the compost temperature and conditions can maximize plant nutrients and biotic properties. Artisan thermophilic compost is appropriate for compost tea, but the quality can vary significantly depending on the feedstock and handling.

Commercial large scale

Large scale operations serve the purpose of processing large amounts of waste material. Generally, this type of compost is best used as a soil amendment, rather than for compost tea, because of low levels of mineral nutrients and biological activity.

(Photo: Nguyen Hue)

Why is verimicompost so great?

Vermicompost quality will vary depending on many factors including worm species, raw materials used, and age of the compost. Vermicomposts are generally of finer structure, contain more nutrients, and have higher microbial activity than other types of compost. Worms facilitate two sets of processes: gut associated processes and cast associated processes (Dominguez 2004). In gut associated processes, several things occur: the fractionation and homogenization of materials, the addition of sugars, the modification of microbial populations and the addition of mucus and excretory compounds (e.g. urea and ammonia). In cast associated processes, high mesophilic microbial activity further decomposes and mineralizes the material under protected (i.e. covered, moist, dark) conditions (Fig. 3). Both processes contribute to the relatively high maturity indicators and positive plant growth response observed in vermicompost compared to other types of composts.

The University of Hawaii compared select quality characteristics of thermocomposts and vermicomposts from various sources (see table 1.1). One benefit of vermicomposts is the relatively large amount of plant available nitrogen that they contain in the form of nitrate ($NO3^-$). This is partly due to the enclosed nature of vermicomposting that reduces losses of $NO3^-$ and other nutrients. Allowing vermicompost to cure (stored in aerated container that conserves moisture) after harvesting for 3-4 months can also dramatically increase the $NO3^-$ content (see figure 3). Note the high CV levels indicate a great deal of variation in mineral nitrogen from sample to sample.

Figure 3: $NO3^-$ increases exponentially over time in cured vermicompost, after removal of worms. Data points in figure below are means of three analyses; bars are standard error of the means. "Curing" refers to the finishing of compost after the active composting process. Compost stored under warm conditions in plastic bags or bins to retain moisture will continue a prolonged mesophilic stage that results in bulid up mineral nutrients and other compounds. These composts have been found to be most effective for use in compost tea (Chapter 3).

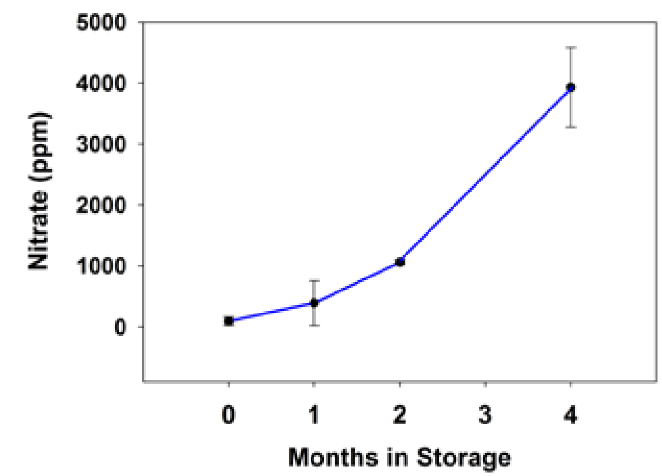


Table 1.1 Select nutrients found in vermicompost and thermal compost available in Hawaii. Analisis were conducted on 157 compost samples 2006-2011.

									--------PPM------	
Method	Feedstocks		# of Samples		N	C:N	P	K	NO_3-N	NH_4-N
Vermicompost	Foodwaste	Mean	42		2.11%	12:1	0.79%	1.47%	1672.2	141
		Range			0.89-4.59%	5.1-25.1	0.06-2.06%	0.06-4.83%	267-2986	2-969
		CV			39%	27%	70%	98%	93%	164%
	Manure	Mean	59		1.67%	14:1	3.04%	0.55%	1988.88	185
		Range			1.29-2.25%	10:1-18:1	0.40-6.03%	0.08-2.39%	316-4824	1-2063
		CV			15%	15%	53%	111%	72%	255%
Thermal	Greenwastes	Mean	28		1.28%	21:1	0.45%	0.77%	634	21
		Range			0.67-2.72%	8:1-40:1	0.14-0.92%	0.21-1.12%	35-1913	0-175
		CV			37%	42%	47%	30%	80%	369%
	Manure & mortalities	Mean	28		1.77%	19:1	1.69%	1.68%	3834	243
	Mortalities	Range			0.61-3.01%	10:1-26:1	0.21-3.78%	0.48-3.13%	60-8625	26-1813
		CV			42%	47%	70%	58%	79%	163%

CV - Coefficient of variation is an indicator of the variation within the compost samples for that nutrient.

N - nitrogen, **C:N -** Carbon to nitrogen (see page 8,) **P -** phosphorus **,K -** potassium**, NO3-N -** nitrate N, **NH4-N -** amonium N

OK for Organics?

Compost Use - NOP Rule 205.203(c)) for compost use states that compost is compliant for use in certified organic systems if three conditions are met:

1. Compost is made from only allowed feedstock materials;
2. the compost undergoes an increase in temperature to at least 131ºF (55ºC) and remains there for a minimum of 3 days; and
3. the compost pile is mixed or managed to ensure that all of the feedstock heats to the minimum temperature for the minimum time.

If composting in windrows, Plant and animal materials are composted through a process that establishes an initial C:N ratio of between 25:1 and 40:1 and maintains a temperature of between 131°F and 170°F for 15 days, during which period the composting materials must be turned a minimum of five times. Compost that contains no animal materials as feedstock may be used without restriction provided that it contains no prohibited or restricted-use plant materials. Acceptable feedstocks include, but are not limited to, by-products of agricultural commodities processing, and source-separated yard debris or "clean green." Compost that contains more than 1x10^3 (1,000) MPN fecal coliform per gram of compost sampled or more than 3 MPN Salmonella per 4 grams of compost sampled will result in a reclassification as 'manure'. Composts that contains sewage sludge, synthetically fortified compost starter, glossy paper, and materials containing colored ink are prohibited.

Frequently Asked Question:

How much time between foliar applications and harvest?

This an area still in development. At the time of printing, there are no explicit restrictions in the NOP guidance or NOSB recommendations on pre-harvest interval as long as the compost is produced according to the NOP guidelines described above and NO MICROBIAL FOODS ARE USED. If microbial foods are used, the resulting tea must be tested for pathogens (e.g. E. Coli O157 and Salmonella). If the tea is found to be clean then future testing is not required if the brewing process and compost are not changed.

OMRI's current interpretation of compost tea is much more conservative. They consider all compost teas to be raw manure regardless of compost type. That means 90-120 days pre-harvest interval (see facing page).

We suggest avoiding manure based inputs and retesting for pathogens each time protocols or inputs are changed. If your tea is non-manure based and pathogen free, a pre-harvest interval may not be needed, but some consumers may not like the idea of spraying with microbes (even good ones) right before harvest.

Tea Use - The NOP is vague on the use of compost tea. In its 2006 recommendation, the National Organic Standards Board (NOSB) defined tea as a water extract of compost produced to transfer microbial biomass, fine particulate organic matter, and soluble chemical components into an aqueous phase, intending to maintain or increase the living, beneficial microorganisms extracted from the compost. The final NOSB recommendation stated "Recommendation: Compost teas if used in contact with crops less than 120 days before harvest must be made from high quality compost described above and not prepared with addition of supplemental nutrients such as sugars, molasses or other readily available (soluble) carbon sources."

The NOSB recommendations also state:

1. Compost teas must be made with potable water.
2. Equipment used to prepare compost tea must be sanitized before use with a sanitizing agent as defined by 21 CFR 178.1010, using allowed materials found on the National List.
3. Compost tea must be made with compliant compost or vermicompost, using the NOSB recommendation for compost and vermicompost mentioned above, and as defined in section 205.203 (c) (2) of the NOP rule.
4. Compost tea made without compost tea additives can be applied without restriction. Compost tea made with compost tea additives can be applied without restriction if the compost tea production system (same compost batch, additives, and equipment) has been pre-tested to produce compost hat meets the EPA recommended recreational water quality guidelines for a bacterial indicator of fecal contamination (US EPA, 2000).

The Organic Materials Review Institute's classification of compost tea as raw manure is extremely conservative and seemimgly incongruent with NOSB and NOP guidance:

> *"Compost tea used as a fertilizer or soil amendment is subject to the same restrictions as raw, uncomposted manure. It may only be (i) applied to land used for a crop not intended for human consumption; (ii) incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with the soil surface or soil particles; or (iii) incorporated into the soil not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles. Compost tea made on the farm may be used to suppress the spread of disease organisms. Compost tea sold for disease suppression must comply with all pesticide regulations. "* (OMRI, 2011)

Brew Master - 1

Gerry Ross and Janet Simpson
Kupa'a Farms, Maui

Type of Operation: Organic
Years using compost tea: 6
Row crops: Potatoes, sweet potatoes, taro, lettuce, brassicas, beans
Green house: cucumbers, tomatoes, and peppers,
Trees: Coffee, citrus, mango, longan, papaya

Source compost

Compost type: Farm produced thermophilic and vermicompost
Feedstock: greenwaste, fish waste, wood chips, rock powder, seaweed

Extraction

Method: Aerated using GEOTEA 250 gallon brewer (see page 21).
Ratio by volume: 125:1
Brewing time: 20 hours
Supplements: For each 250 gal brew cycle, we add 2 c 3-2-2 enzyme digested fish, 3 c Humax, 2 c Maxicrop, 5 gal seawater, and 5 gal rock milk. To make rock milk, mix quarry basalt rock powder with water, and allow to settle for 10-15 minutes then pour off and add the brown milky water to the tea.

Application

Application method: Drench/root soak applied using a 3/4 inch hose with a non-clogging spray nozzle (20 foot reach) and 1 HP Honda pump. At the time of application, we add 2 cups fish and 4 oz of an organic spreader (NuFilm or Natural Wet which comes from Yucca shidigera) for each 50 gallon increment.
Coverage: About 100 gal per acre undiluted
Frequency: Every week to 2 weeks we cover about a third of the farm with our main veg production areas getting it weekly.

Observed benefits

While it is sometimes difficult to separate the benefits of the tea from other practices we have used, especially cover crops, we have seen a dramatic improvement in our soil which now has wonderful tilth and biologically diverse soil life. Even though it is a silty stony clay-rich soil, it has excellent aggregation with lots of pore space for air, water and root penetration. We see good responses from potatoes, keeping the bacterial wilts off long enough to get a healthy crop. Chard and the rest of the beet family as well as most vegetables respond very well for us.

Gerry and Janet's Advice

We use the tea to help digest cover crops: we mow, disc and then spray on tea to speed up their breakdown. Absolutely essential is good compost...we fuss over our compost and do seedling tests with cress to make sure it is mature. It is important to spray early in the day before it gets too hot. I also recommend spraying on cloudy days and using a spreader sticker to reduce microbe loss from UV. Following an irrigation cycle or rain gives the microbes a moist refuge they can move into at the time of application. The criteria we use to evaluate the tea quality are lots of foaming and no off odors.

Kupa'a On-Farm Trials

Objective: Quantify yield of specialty potatoes grown with and without compost tea in an organic production system on Maui.

Trial Set-up: Three potato varieties ('Cranberry', 'All Blue' and 'Onoway') were planted to 200 foot rows at approximately 2000 feet elevation in Kula Maui. A preceding barley cover crop, seeded at 70 lbs/acre, had been incorporated 6 days before potato planting. Seed pieces were cut to have 1-3 eyes then immediately coated in a commercial mycorrhizal preparation (Glomus interradices, www.mycorrhizae.com) and planted in raised beds with ~3 ounce of mature compost per seed piece. Potatoes were spaced 1 foot between seed pieces within rows, and 8 feet between hills. Compost tea was applied as per grower practice (see opposite page), but was withheld from four sections within each row (i.e. 4 replications per row). Compost tea was produced and applied three times during the crop cycle, about every 3 weeks. Potatoes were harvested 72 days after planting for a "Red, White and Blue" mix to marketed for 4th of July. Total and marketable yield per 90 ft2 plot (3ft wide x 30 ft long) and average weight of individual potatoes were determined for each variety.

Trial Duration: April 4, 2009 - July 1, 2009.

Results Summary: Yield and concentrations of total phenolic compounds were significantly influenced by variety. Tea applications did not have a significant effect on either marketable or unmarketable yields of the three varieties, nor did it significantly impact total phenol levels. Phenolic compounds are important because they contribute to the color and antioxidant potential of produce. In this on-farm trial, variety selection was more impactful on potato yield and quality than compost tea applications.

Chapter II - Compost Tea Production

Archana Pant, Theodore Radovich, Nguyen Hue

Extraction Methods

Two dominant approaches of compost tea production are aerated and non-aerated methods. Scheurell and Mahaffee (2002) and Ingham (2005) used the terms non-aerated compost teas (NCT) and aerated compost teas (ACT) to refer to the extracts produced by these methods. ACT refers to methods in which the mixture is actively aerated during extraction. NCT refer to methods that do not disturb or only minimally disturb the extraction after initial mixing. Other terms used to describe aerated and non-aerated compost teas are: aerobic and anaerobic, or active and passive. Aerated and non-aerated, however, seem to most accurately describe the different processes used in production as well as the end-product (Scheuerell and Mahaffee, 2002).

Both extraction methods involve the steeping of compost in water for a defined period at room temperature. Aerated compost tea requires aeration throughout the extraction period (Weltzien, 1991; Scheuerell and Mahaffee, 2002). Weltzein, as a pioneer in this area, focused primarily on non-aerated method of compost tea production in the late 1980's and early 1990's (Weltzein and Ketterer, 1986; Weltzien, 1991). However, in recent years, interest has shifted to the ACT method (Scheuerell and Mahaffee, 2002). From a grower's perspective, ACT has the distinct advantage that it can be prepared in 1-2 days and results in less odor problems, whereas, NCT requires 1-2 weeks steeping time (Ingham, 2005). Non-aerated compost tea does not require any special technology beyond a steeping vessel and is associated with low cost or low energy input, whereas, ACT requires constant stirring and aerating of large volumes of liquid. Proponents of ACT production argue that the risk of contamination by human pathogens is very low in ACT compared to that of NCT, as the human pathogens including E. coli are poorly competitive under aerobic conditions, however, there is no documented evidence to substantiate these claims (Brinton et al., 2004).

There is no agreement whether aeration is required. Several investigators have reported that non-aerated compost tea has consistently positive effects on disease control and plant growth in contrast to aerated compost tea (Weltzien, 1991; Cronin et al., 1996; Scheuerell and Mahaffee, 2006). Welke (2005) concluded that both aerated and non-aerated teas have similar effect on plant growth and disease suppression. In contrast, Arancon et al. (2007) reported that aerated vermicompost tea had a greater positive impact on plant growth than non aerated tea extracted for the same period of time (24 hrs). These varying reports of the impacts of compost tea production method on plant health and yield are crop specific and inferences about the superiority of one method over another on disease suppression or plant yield cannot be generalized. When recommended protocols for both methods were trialed concurrently no difference in plant growth were observed (Chapter 3).

Homemade Brewers

The most basic brewer is a 5 gallon bucket with a mesh bag (see illustration). Many people find that using a nylon paint strainer made to fit over the top of the bucket is convenient. Brewers with higher volumes add spigots and support systems for easier draining. The obvious advantage of homemade, non-aerated brewers is lower costs. (See pages 19 for an overview of research comparing non-aerated and aerated tea.)

Non-aerated compost tea requires approximately a 1 week steeping time (Weltzien, 1991).

Aeration requires the addition of an air pump and a device to produce bubbles. Options include using pumps and air stones (see picture at left) from the aquarium industry and perforated PVC pipe or hosing. Many designs are available on-line, however, these have not been evaluated so individual judgement on their effectiveness is required.

Commercial Brewers

Commercial brewers are designed to provide uniform aeration and circulation. Check with individual retailers for information on circulation, oxygen levels and biomass growth. The brewers on the right were selected to demonstrate the range of designs on the market. Please see the suppliers list on page 67 for additional dealers.

Recommendations for brewing time and use of additives vary by manufacturer but are typically about 24 hours. .

Keep it Simple (KIS)

Their smallest system is designed to fit in standard 5 gal buckets. It consists of a pump and perforated PVC piping that is shaped to distribute air across the bottom of the bucket. It has been tested for a 12 hour brew time.

Greater Earth Organics (GEOTEA)

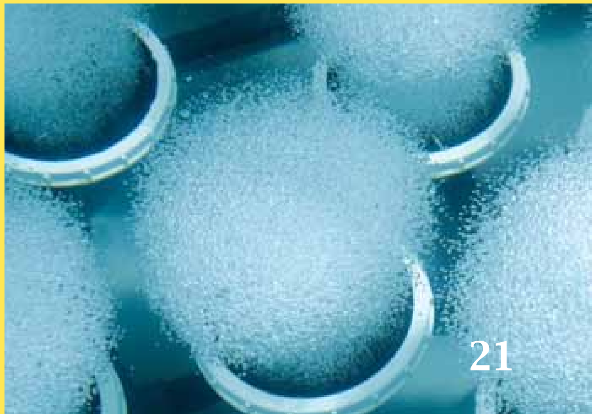
A high volume of rapidly rising bubbles exit a stainless steel air diffuser tube at the bottom of the tank to oxygenate and circulate the tea. At the same time, additional air is pumped out of holes from a tube extending into the compost in the submerged extractor dome.

Living Soils Organics

This design uses a conical tank and an external, vortex creating, aeration system. Each up-feed pipe has an air-stone for bubbles. The bubbles lift the tea up the pipes where it reenters the tank at an angle that results in a circular motion. More liquid is drawn from the bottom of the tank for constant circulation.

Growing Solutions

Aeration is achieved through Fine Bubble Diffusion. This technology was first developed for and has had long-term use by the waste water industry.



Ratio of compost to water

Optimum ratio of compost to water tends to vary, depending upon the brewing process, compost quality and purpose of compost tea application. Too little compost will result in dilute tea with low amounts of nutrients or organisms; whereas, too much compost may not allow maximum amounts of nutrients and microbial biomass of compost to be extracted (Ingham, 2005).

Studies on compost to water ratio have mainly focused on disease suppression effect of compost tea with diverse results. Most studies have followed the methodology developed by Weltzien (1990) that uses a 1:3 - 1:10 (vol:vol) compost to water ratio. Weltzien (1990) reported that there was a significant suppression of *Phytopthora infestans* with the application of compost tea, no difference in suppression was observed for compost to water ratios between 1:3 and 1:10. However, the suppression effect of compost tea was lower with 1:50 compared to 1:3 and 1:10 compost to water ratio (Weltzien, 1990). Welke (2005) observed that strawberry plants had higher yield and lower incidence of disease with the application of compost tea prepared with a 1:8 compared to that of 1:4 ratio. Edwards et al. (2006) reported a non-significant difference on plant growth response of tomato seedlings with the applications of vermicompost teas with 1:25, 1:12 and 1:10 ratios. Several studies indicated that limiting compost to water ratio to 1:10 is found to be effective on disease suppression and yield improvement although the exact mechanism is unclear (Weltzien, 1991; Touart, 2000; Scheuerell and Mahaffee, 2002).

Research at the University of Hawaii (Pant, 2011) showed that application of vermicompost tea with vermicompost to water ratios of 1:10 - 1:100 (by volume) increased plant yield and root growth, and the response to the ratio of vermicompost to water was generally linear. Similar effects were observed in tissue N, phytonutrient content and microbial activities in soil. The best plant growth response was observed with vermicompost to water ratios of 1:20 and 1:10, indicating that the optimal ratio of vermicompost to water ranges between 1:10 and 1:20.

Frequently Asked Questions:

Compost to water ratio and application rate

How much compost do I need to use?

A 1:10 - 1:20 ratio of compost to water is recommended. Benefits decrease in a linear fashion as the solution becomes more dilute, but some effect is seen with solutions as low as 1:100. The decision on concentration is generally based on compost cost and quantity of tea required. To get a 1:10 ratio you add a little over 1 1/2 cups compost for every gal of water.

How many gallons should I be using per 1000 square feet?

Optimal growth in our research was seen at an application rate of 7-14 gal per 1000 sq ft (300-600 gal per acre). This rate allows for some penetration into the root zone when applied foliarly. Weekly applications are recommended for at least 4 weeks in vegetable crops.

I buy vermicompost by the pound,what is the conversion?

One gallon of vermicompost weighs around 4-5 pounds. However, It is still best to measure the volume as the weight of compost varies by the moisture content.

What is the best way to apply compost tea?

For small areas, applying with a watering can is probably easiest. For larger areas, tea may be pumped through a hose or sprayer. Injection through drip lines is possible, but requires filtering and flushing of the lines with fresh water after application. We recommend that at least some portion of the compost tea be applied to the root zone.

How do get the most bang for my compost tea buck?

Research in Hawaii suggests that much of the impact on plant growth is due to improved nutrient availability, particularly nitrogen. Compost tea may have the greatest impact in low input environments where nitrogen availability is expected to be low. The use of high quality compost applied at the rates recommended above would be expected to improve plant nutrient status and growth.

Conversions:

1 gallon = 3.8 liters 1 pound = 0.45 kilograms

Brewing (extraction) period

Brewing (extraction) period is an important factor contributing to compost tea quality and efficacy. Compost tea should be brewed to an extent when most of the soluble nutrients and organisms from the compost are extracted or pulled out into the solution (Ingham, 2005). Too short brewing period may prevent maximum extraction of nutrients and microbial biomass from the compost whereas too long brewing period may favor microbial immobilization of extracted nutrients leading to microbes become inactive once all the available foods are immobilized (Ingham, 2005). Similarly, Scheurell and Mahaffee (2002) noted that effectiveness of compost tea increases with increasing brewing time to a maximum and then declines. Brewing period of compost tea may vary with brewing methods, compost source and purpose of compost tea application.

Non-aerated compost tea generally requires a longer brewing period compared to that of aerated tea (Brinton et al., 2004; Ingham, 2005; Diver, 2001). Weltzien (1991) reported that usually a 5 to 8 day period and up to a 16 day brewing time is needed for NCT, which has been hypothesized to allow sufficient time for facultative anaerobes to dominate and for their metabolites to accumulate. Ketterer et al. (1992) examined Botrytis suppression on detached grape leaves with 1, 3, 7 and 14-day brewed NCT, and that the maximum suppression was observed with the application of 7-day brewed tea.

Ingham (2005) suggests that the optimum brewing time for ACT co incides with maximum active microbial population in the tea, often 12-24 hours with commercial aerobic compost tea makers. Schurell and Mahaffee (2002) citing Cantisano (1998) stated that one day brewing of ACT would be effective for foliar feeding while longer brewing period up to 14 days is useful for disease control.

Research on compost tea brewing period have focused primarily on disease suppression effects; further research work on effect of compost tea brewing period on plant growth is needed.

Frequently Asked Questions:

Extraction and brewing

Do I need to use aeration?

Not necessarily. There is some evidence to suggest that if brewed for longer periods of time non-aerated teas can produce similar effects as aerated compost teas. The primary benefit to aeration is to shorten the extraction time. Other reasons for using aeration include increasing oxygenation to promote aerobic activity and to avoid potential for bad smells and phytotoxic compounds that can result from anaerobic activity. More research is needed to determine when aeration is ideal or necessary.

Do I need to add supplements to my brewer?

Not necessarily. While supplements, particularly sugar, can increase microbial populations, evidence linking increased microbial populations to enhanced plant growth is not conclusive. Teas made with high quality teas without supplements have been shown to be effective. Supplements may be an issue for growers with organic certification (see pages 14-15).

How long can I keep the tea after brewing?

The convention is to use the tea within 4 hours, however research at Ohio State University has shown that refrigeration can extend efficacy for up to 14 days. (citation Arancon)

What are the characteristics of high quality tea?

The characteristics of the tea reflect the characteristics of the compost used. Brewing, when properly managed, extracts the soluble nutrients and preserves the biological characteristics of the compost. Biological characteristics of high quality compost teas have been proposed (see Ingram, 2005). Chemical characteristics of high quality include high levels of available nitrogen, humate, and gibberelic acid.

What about chlorine or chloramine in the water?

Clorinated water can be degassed by allowing the water to sit overnight or letting the aerator run for several hours. Chloramine is chlorinated ammonia and is used as an alternative to chlorine in some situations. It is much more difficult to remove (check with your water supplier).

Brew Master - 2

Alex Karp
Island Harvest Organics
Pahoa, Hawaii

Type of Operation: Certified Organic
Years using compost tea: 2
Green house: tomatoes, sweet bell peppers

Source compost

Compost type: on-farm vemicompost

Extraction

Method: aerated, Glen Matinez' brewer design
Ratio by volume: 2lbs compost to 50 gal water
Brewing time: 24 hrs
Supplements: molasses only used if brew is not consumed within 4 hours

Application

Method: Drip
Concentration: 50 gallons for 7000 sq ft greenhouse
Frequency: Once per week

Observed benefits

Increased plant growth

Advice

Try to use up brew within 4 hours, or add molasses if this is not possible. Be careful with foliar spraying of seedling starts because they may get burned.

Chapter III - Using Compost Tea to Increase Plant Growth and Quality

Archana Pant, Theodore Radovich, Nguyen Hue

Use of compost tea as a foliar spray or soil drench has been demonstrated to improve plant health, yield and nutritional quality by: (i) enhancing beneficial microbial communities and their effects on agricultural soils and plants; (ii) improving mineral nutrient status of plants; and, (iii) inducing the production of plant defense compounds that may have beneficial bioactivities in humans (Weltzien, 1991; Hoitink et al., 1997; Scheuerell and Mahaffee, 2002; Carpenter-Boggs, 2005; Ingham, 2005a; Diver, 2001). The potential benefits of compost tea are substantial and particularly relevant to crop production in low-input agricultural systems.

Most of the previous research on compost tea has investigated the potential of compost tea for control of plant disease. Pant et al. (2011) conducted a series of experiments to determine the effects of vermicompost tea on plant growth, yield and nutrient quality of pak choi; and soil biological properties. Specifically, the effects of vermicompost tea extraction methods [(i) non-aerated (NCT), (ii) aerated (ACT), and (iii) aerated with additives (ACTME)], fertilizer types (Osmocote and vermicompost), and three growth media (Oxisol, Mollisol and a peat-perlite medium) on yield and nutritional quality of pak choi (Brassica rapa, Chinensis) as well as soil biochemical properties were evaluated. The effects of the ratio of vermicompost to water and different fertilizers on yield and nutritional quality of pak choi as well as soil biological properties were assessed. Also, the effect of compost quality on biochemical properties of compost tea; and mechanisms involved in the effects of compost tea on plant growth were determined.

Applications of vermicompost tea, regardless of extraction method (ACT, NCT or ACTME) enhanced yields, total carotenoids, total glucosinolates and mineral nutrients of pak choi across the fertilizer regimes and this effect was most prominent under organic fertilization in an Oxisol, a Mollisol or a peat-perlite medium (see figures 3.1 & 3.2). Vermicompost tea improved mineral nutrient contents and microbial properties of these growth media. The vermicompost tea effect on crop growth was attributed largely to additional mineral nutrient uptake by plants. This finding suggests that vermicompost tea can positively influence plant yield and quality and increase soil biological activity in multiple soil types. Similarly, application of vermicompost tea with compost to water ratios of 1:10 - 1:100 (v:v) increased yield, total carotenoids, total glucosinolates and N content of pak choi; and microbial activities in soil. The responses of these parameters to vermicompost to water ratio was positive and linear. The best plant growth response was observed with vermicompost to water ratios of 1:20 and 1:10, (see page 29) indicating that the optimal ratio of vermicompost to water ranges between 1:10 and 1:20. The results also indicated that biochemical properties of compost determined biochemical properties of compost tea, and variability in quality of tea explained differences in the magnitude of effect of compost tea on plant growth and tissue mineral nutrient. The positive effect of vermicompost tea or compost tea on plant growth was largely associated with N (NO3-) and gibberellin (GA4) present in the tea and nutrient uptake by plants.

Effect of Compost Tea on Yield in Greenhouse Trials

Applications of vermicompost tea, showed a positive effect on yield regardless of extraction method (see figures 3.1). These positive effects were seen in pak choi plants that were fertilized with either compost or Osmocote. The impact of vermicompost tea on crop growth was largely attributed to additional mineral nutrient uptake as evidenced by a linear relationship between the above ground dry weight of the plants and their nitrogen content (see Figure 3.2). Growth was also attributed to the bio-chemical properties of the compost tea (see page 30).

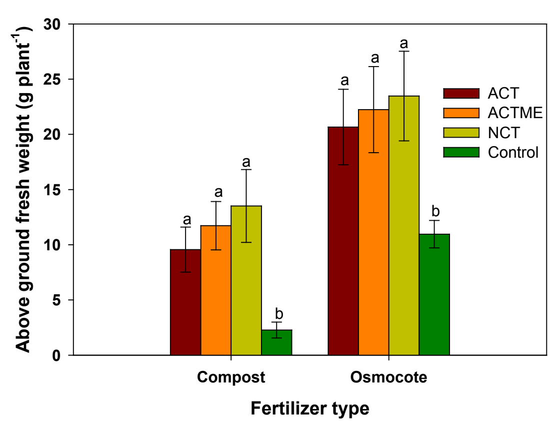


Fig. 3.1 Above ground fresh weight as affected by compost tea application.

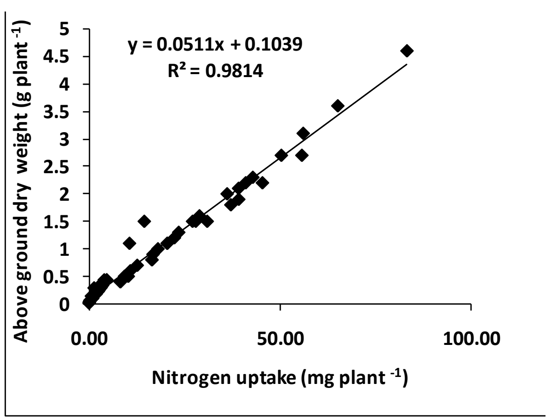


Fig. 3.2 Relationship between plant growth and N uptake.

Figure 3.3
Pak choi grown in Mollisol (Waialua series, very-fine, kaolinitic, isohyperthermic, Vertic Haplustolls)

Pak choi grown in Oxisol (Wahiawa series, clayey, kaolinitic, isohyperthermic, Tropeptic Eutrustox)

Pak choi grown in peat-perlite medium

photos: A Pant

Figure 3.3 Evaluation of the effect of compost tea applications on pak choi yield under 5 conditions: Aerated compost tea with added microbial enhancer (ACTME), Aerated compost tea (ACT), Non-aerated compost tea (NCT), NPK solution (NS) with nitrogen levels matched to those found in the compost tea, Water (control)

The plants were grown in a greenhouse with one of the four solutions or water applied weekly for four weeks. All compost teas increased plant growth. The results were consistent in three different growth media: Mollisol, Oxisol and a peat-perlite.

Biochemical properties of compost tea affecting plant response

Mineral Nutrients in compost tea

Compost tea contains a considerable amount of soluble mineral nutrients that are readily available for plant uptake and promote crop growth and yield (Welke, 2005; Hargreaves et al., 2009; Pant et al., 2009; Azza et al., 2010). Mineral nutrient concentration in compost tea generally varies with compost source, compost age and compost tea extraction methods. Hargreaves (2008) stated that NCT produced from ruminant manure compost contains 315:43:122 mg L^{-1} N:P:K, 23 Ca and 13 Mg; whereas NCT produced from municipal solid waste compost contains 58:11:188 mg L^{-1} N:P:K and 68 Ca and 21 Mg. Pant et al. (2009) reported that ACT and NCT produced from chicken manure-based vermicompost contain 80:16:180 mg L^{-1} N:P:K, 49 Ca and 43 Mg (see table 3.1). Higher levels of N, K, Ca and Mg in ACTME is due to those present in the additives (humic acid and kelp). Compost tea and vermicompost tea also contain a considerable amount of micronutrients and macronutrients (Hargreaves, 2008; Pant et al., 2009)(see table 3.2).

Table 3.1 Macronutrient content in vermicompost tea across extraction methods (n = 8).

Extraction method	N	NO_3-N	NH_4-N	NO_2-N
	mg L-1			
NCT	74.9(4.6)†	73.3(4.5)	0.6(0.2)	0.3(0.0)
ACTME	106.9(6.3)	97.5(6.1)	8.3(0.7)	0.5(0.0)
ACT	81.7(4.4)	80.2(4.4)	0.5(0.1)	0.4(0.0)
Control	9.6(1.8)	9.0(1.7)	0.3(0.2)	0.1(0.0)

Extraction method	P	K	Ca	Mg
	mg L-1			
NCT	16.2(1.0)	166.6(10.3)	48.6(2.2)	42.8(2.3)
ACTME	16.5(1.1)	656.1(21.7)	83.4(3.6)	61.5(3.4)
ACT	16.2(1.7)	180.4(5.9)	49.0(2.8)	43.9(2.3)
Control	0.2(0.1)	5.61(1.3)	12.4(0.3)	15.3(0.2)

† Parenthesis show standard error, NCT = Non-aerated vermicompost tea, ACTME = Aerated vermicompost tea with microbial enhancer, ACT = Aerated vermicompost tea, Control = water.

Table 3.2 Micronutrient content in vermicompost tea across extraction methods (n = 8).

Extraction method	Fe	Mn	Zn	Cu	B
	µg L-1				
NCT	0.0(0.0)†	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.3(0.0)
ACTME	1.5(0.1)	0.3(0.1)	0.6(0.1)	0.4(0.1)	0.6(0.1)
ACT	0.1(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.3(0.0)
Control	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)

† Parenthesis show standard error,

Phytohormones in compost tea

Compost tea may contain phytohormones or plant growth regulator-like substances which contribute to better plant growth and yield. It is believed that greatly increased microbial population during composting would produce plant growth regulator-like substances. Ali et al. (2009) demonstrated that various strains of bacteria such as Bacillus, Pseudomonas, Escherichia, Micrococcus and Staphylococcus genera associated with wild herbaceous flora are able to synthesize indole-3 acetic acid (IAA). The authors also reported that most of the bacterial strains of Pseudomonas and Bacillus genera enhanced endogenous IAA content and growth of Triticum aestivum. Similarly, Ali and Hasnain (2007) observed that RE1 strain of Halomonas desiderata produced IAA that has similar effects to other synthetic and natural auxins on in vitro growth of Brassica oleracia. Garcia Martinez et al. (2002) showed that a compound with molecular structure and biological activity analogous to auxins was present in compost. The authors also reported similar biological activity and growth promotion effect of water based compost extract and IAA treatments on garden cress (Lepidium sativum). Leachate from well decomposed compost has been shown to contain cytokinin-like substance, derived from hydrolysis of glucosides by the enzyme β-glucosidase produced by microbes (Arthur et al., 2001).

Various studies have postulated that vermicomposts contain a large amount of plant growth regulators such as gibberellins, auxins, and cytokinins produced by the increased microbial populations resulting from earthworm activity (Atiyeh et al., 2000, a; Arancon et al., 2004). These studies have concluded that application of vermicompost increases seed germination, seedling growth, flowering of ornamentals, and yield of vegetables even at low substitution rates regardless of nutrient supply. Edwards et al. (2006) observed better growth of tomato seedlings treated with vermicompost tea compared to water (control) and suggested that presence of plant growth regulators in vermicompost tea is responsible for growth promotion effect, but the authors did not report on the amount of any phytohormones present in vermicompost tea. Pant (2011) reported that extracts of chicken manure-based thermophilic compost, food waste vermicomposts and chicken manure-based vermicompost contained Gibberellin4 (GA4) and Gibberellin34 (GA34). It would be reasonable to believe that phytohormones present in compost or vermicompost would be extracted in the tea during brewing process.

Nutritional Quality of Crop

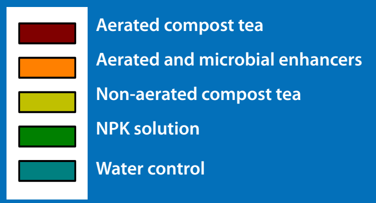
Secondary plant metabolites such as carotenoids, glucosinolates, and phenolic compounds are often called phytonutrients. These molecules are known to play a major role in the adaptation of plants to their environment and also have important implications to human health, crop flavor, and commodity value because of their demonstrated biological reactivity and association with anti-oxidative and anti-carcinogenic activity in humans (Radovich et al., 2005).

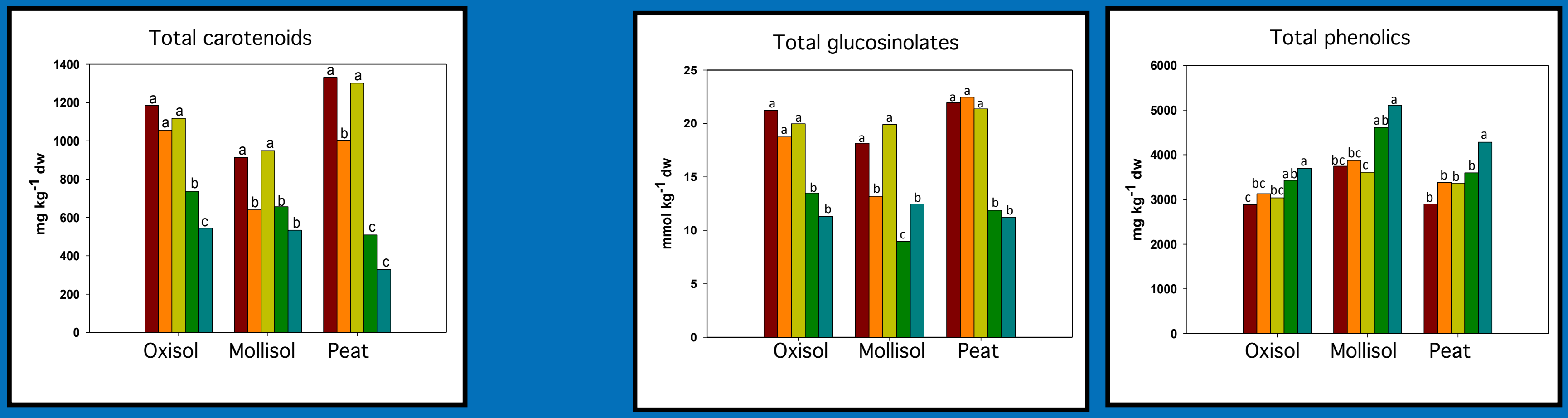
Anti-oxidants (e,g. total phenolic and carotenoids) are vital to prevent damage due to pollution in plants, and to prevent diseases in both plants and animals. They play a very important role in scavenging reactive oxygen species and in the body defense system (Ou et al., 2002). Vegetable crops, particularly cruciferous vegetables, act as good sources of nutritionally important dietary carotenoids, polyphenols and glucosinolates (Kopsell et al., 2007; Ahmed and Beigh, 2009).

Studies have demonstrated that plant nutrient relations and environmental factors significantly affect the concentration of those plant metabolites in vegetables (Radovich et al., 2005; Perez-Lopez et al., 2007).Perez-Lopez et al. (2007) observed that the use of composted animal manure increased the total carotenoids in sweet pepper (Capsicum annuum). Sanwal et al. (2006) have reported that increased crop yield and dietary anti-oxidants of broccoli occurred with the use of compost and non-aerated compost tea.

Hussein et al. (2006) and Kopsell et al. (2007) reported higher carotenoids in plant tissue to correspond with increased plant growth at higher fertilizer rates, particularly levels of available N. Krumbein et al. (2002) reported that levels of total glucosinolates were reduced at low N fertilizer in broccoli plants, whereas, total glucosinolates levels were increased at sufficient N supply. Pant et al. (2011) reported that application of vermicompost tea increased total carotenoids, total glucosinolates and mineral nutrients of pak choi and this effect was most prominent under organic fertilization in an Oxisol, a Mollisol or a peat-perlite medium (figure 3.4).

Figure 3.4
Phytonutrients in plants treated with different types of compost tea compared to controls treated with water. Bars with the same letter are not significantly different.





Soil biological properties

Soil chemical and biological properties are indicators of soil quality and health, as influenced by management practices. Various studies have shown that organic fertilization improved mineral nutrient status as well as soil biological and physical properties (Tejada and Gonzalez, 2006; Okur et al., 2008). Rhizosphere properties are strongly influenced by management practices and sensitively reflect the change and dynamics in soil quality and health (See Brew Master 4 on page 40).

Microbial respiration and dehydrogenase enzyme activity are often considered to be a good index of total microbial activity in soil (Nannipieri et al., 1990). Arancon (2001) reported significant increases in dehydrogenase activity in soils treated with vermicomposts coinciding with the soil microbial biomass. Various other studies suggested that application of different types of thermophilic compost increased soluble carbon and soil respiration (Sikora and Yakovchenko, 1996; Bernal et al., 1998; Lalfakzuala et al., 2008). These increases would be attributed to the intense activity of the soil microorganisms in degrading easily metabolizable compounds such as active organic carbon added through compost or vermicompost. Application of tea potentially can add a huge numbers of active microbial populations and mineral nutrients to the soil. Microbial biomass in compost tea provides a source of nutrients and plays an important role in soil organic matter mineralization, improving the synchrony of nutrient release to meet crop demand.

Pant et al. (2011) reported that application of vermicompost tea improved biological properties of an Oxisol, a Mollisol and a peat-perlite media in greenhouse and field conditions. Vermicompost tea treatments contributed to increased microbial respiration (μmol CO_2 fluxes m^{-2} sec^{-1}) and dehydrogenase activity (μg TPF g^{-1} soil), particularly under compost fertilization, implying more efficient organic matter decomposition and mineralization of nutrients in soil, and therefore producing better plant growth. Application of vermicompost tea also improved mineral nutrient concentration in an Oxisol, a Mollisol and a peat-perlite medium.

Brew Master - 3

Tane and Maureen Datta
Adaptations, Kona, Hawaii

Type of Operation: Certified Organic
Years using compost tea: 10 years
Apply tea to: Leafy crops that are prone to fungal diseases

Source compost

Compost type: Thermophilic and vermicompost
Compost source: From Keep IT Simple for quality and consistency during our research. Now shifting toward homemade leaf and worm compost

Extraction

Method: Aerated, 5 gal KIS with high quality pump
Ratio by volume: 4 cups /5 gal bucket, ~1:20
Brewing time: 24 hours off at night due to solar power
Supplements: None due to organic standards and food safety restrictions

Application

Method: Spray and drench
Coverage: 5 gal/1000 ft
Frequency: Weekly

Observed benefits

Benefits were variable, decreasing with time as the general micro eco system strengthened. Helps most against molds on leaves that get good air flow. Helps least on lettuce and can actually hasten some diseases.

Advice

The best advice I was given was to use several sources of compost, some just finished thermophilic, some several year old wood based with white fungus on it, and some vermiculture.

It continues to be a learning process. Due to restrictions from organic certifiers and developing food safety restrictions, I have had to switch to Mycotrol O and Serenade for bugs and disease control. I am developing a method to increase production field vermiculture. I am growing all sorts of visible critters and therefore building soil and therefore have easy to care for, healthy plants.

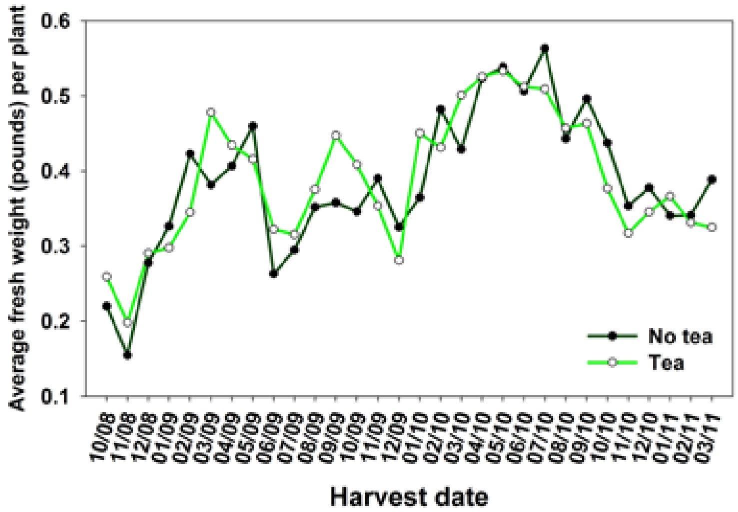
Adaptations On-Farm Trials

Objective: Observe Pak Choi (Brassica rapa group chinensis) yields for 29 months from 2 beds receiving tea applications regularly, and 2 beds that did not receive compost tea.

Trial Set-up: Four beds (4' x 30') in close proximity to each other were randomly assigned either "tea" or "no tea" treatment. Tea was applied weekly via a back pack sprayer to the "Tea" beds. The primary varieties used were 'Fuyu' and 'Shogun.' Seedlings were grown under identical conditions in the greenhouse and planted out to beds approximately 20 days after seeding. Once transplanted, seedlings were managed under similar conditions (fertilizer, irrigation etc), with the exception of tea applications. Plants were harvested at market maturity (20-40 days after transplanting). At harvest, fresh weight of individual heads, and notable defects were recorded. Approximately 300-400 plants were harvested per month from each treatment (~150-200 plants per bed/ month)

Trial Duration: Continuous from October 2008 to March 2011.

Results Summary: Seasonal differences in yield across beds were much greater than yield differences between "Tea" and "No Tea" beds. Yield differences between beds were generally inconsistent, although there was a greater frequency of heavier yields in the first year from "Tea" beds compared to "No Tea" beds. The relatively small and inconsistent effect of tea may be partly explained by high fertilizer applications in all beds throughout the project period, and a change in tea production practices in the second year of the project.



Observations by Grower: "As a whole, we saw decreasing differences between the compost tea beds and the non-tea beds. This may be because the 1/8 cup of fertilizer we gave each plant and the care we gave to the beds equalized and improved the soil quality. Nursery techniques, planting time, transplanting care, which is to say basic horticultural techniques were a bigger factor in producing consistent quality plants than the tea. Another important factor is the tea was forced to change over time. Even though we started with the same type compost from the same company. After the first year, organic certification and food safety requirements prohibited the addition of nutrients. I think this lowered the quality of the tea."

Frequently Asked Question:

Does it Work?

Researchers: Ted Radovich, Jari Sugano and Jensen Uyeda

Grower cooperator: Ho Farms

Yes, depending on conditions. Compost tea has been demonstrated to have the potential to promote plant growth in green house trials (see Chapter 3) despite inconclusive results from earlier on-farm trials (see Master Brewers 1 & 3). Grower use of compost tea in the field is generally limited by labor and material costs, which may preclude use of composts at highest recommended rates when producing and applying tea. Injection of tea through the irrigation system minimizes labor associated with spraying, applies tea directly to the root zone and avoids spaying leaves of crops. An experiment was conducted to evaluate the efficacy of compost tea made from small quantities of farmer produced thermophillic composts on pak choi growth in the field when applied through a drip system

Objective: To quantify the impact of compost tea on field grown pak choi using thermophilic compost produced from on-farm feedstock in a brewer constructed from local materials.

Trial setup: Compost was produced in static piles from tomato and cucumber culls and wood chips by Ho farms (Kahuku). Feedstocks were combined and composted in bins for 6 months. A field experiment using pak choi variety 'Red Choi' was conducted at Waimanalo Field Station of the University of Hawaii. Five replications of two treatments; tea or no tea. Individual plots were 300 ft^2. One half of a gallon of compost was extracted weekly in 50 gallons of water (100:1). Tea was applied through the drip system at a rate of 300 gallons per acre on a weekly basis. Drip tape was flushed with clean water after tea applications. Pak choi plants were harvested 6 weeks after transplanting.

Trial duration: Compost production, March-August, 2009; Field trial February-April, 2010.

Trial results: Tea applications resulted in subtle, but significant increases in dry matter production in pakchoi heads after 5 weeks (Figure A). On a fresh weight basis, heads in plots receiving tea were 14% heavier than heads not receiving tea. Assuming a planting density of 29,000 plants per acre, yields in this trial are extrapolated to be 7.7 and 6.6 tons per acre for tea and no tea plots, respectively. Assuming a wholesale price of $1.50 per pound, this translates to a potential increase in farm-gate value of $3,300 per acre in the tea plots. Although it is not possible to determine the exact costs of the on-farm produced compost, it is estimated at $50 a yard (1 cubic yard = 202 gallons of compost). If 300 gallons of tea are applied 4 times during the crop cycle, this is equivalent to 10 gallons of compost at a 100:1 ratio, or $3.00 of compost for the whole crop. Even if the highest prices for vermicompost are used ($3/pound or $57 per acre), the cost benefit appears to be favorable.

Discussion: This study was designed specifically to evaluate a system of tea production and application that was both feasible for growers and in agreement with our current understanding of the optimal rates of compost tea for improving plant growth. Although impacts of compost tea have been difficult to measure in complex production systems, it does appear that there is potential for tea to increase the profitability of farming systems. Each farm manager should independently evaluate the potential for beneficial use of compost tea in their system. Current recommendation include using <100:1 ratio of water:compost by volume and weekly applications of at least 250 gallons per acre directly to the root zone.

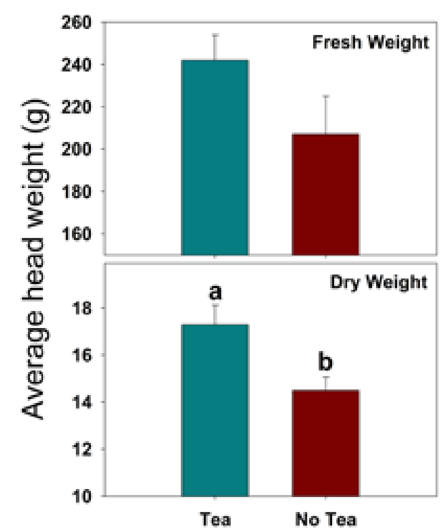


Figure A. Average head weights of pak choi grown with and without weekly applications of compost tea. Values are means of 5 replications . Error bars are standard errors. Different letters indicate significant differences between mean at P<0.05..

Brew Master - 4

Ian Cole,
Breadfruit Institute
Hana, Hawaii

Type of Operation: Botanical Garden
Years using compost tea: 1
Greenhouse: Breadfruit (Artocarpus altilis)
Orchard: Breadfruit (Artocarpus altilis, Artocarpus mariannensis, hybrids of those 2 species and Artocarpus camansi)

Source compost

Compost type: Vermicompost and thermophilic
Compost source: On-site, locally produced and store bought

Extraction

Method: Aerated, Growing Solutions 100 gal
Ratio by volume: 10: 1
Brewing time: 24 hours
Supplements: fish hydrosylate, kelp, Growing Solutions "booster"

Application

Method: Soil Sprench, foliar
Coverage: 66-100gal/acre
Frequency: Once per week

Observed benefits

Not much observable differences in our mature trees. The soil layer sometimes shows colonies of fungal fruiting bodies that were not observed prior to application, but this may not be directly linked to tea (see page 34.)

Advice

Use simple recipes for large volume applications. If you cannot make your compost on site, you need an affordable source for quality compost.

Chapter IV -
Suppression of Arthropod Pests and Diseases Using Vermicompost Teas

Norman Arancon

Three key contributors to crop infestation and disease:

1. **Availability of a susceptible host**
2. **Presence of causal organisms**
3. **A favorable environment for infestation**

Understanding the relationships between these three components is central to the success of pest and disease management programs.

Organic farmers have long claimed that plants grown with organic amendments are much more resistant to insect pests and diseases than plants grown with synthetic inorganic fertilizers. Scientific literature provides evidence that specific insect attacks are suppressed by various forms of organic amendments. For instance, reports have demonstrated that field applications of composts can suppress attacks by pests such as aphids and scales (Culliney and Pimentel, 1986; Yardim and Edwards, 1998; Huelsman et al., 2000).

Vermicomposts, are produced by mesophilic decomposition and stabilization of organic matter by certain earthworms and microorganism. They have been shown to increase plant growth and yield in addition to suppressing key pests and diseases of horticultural plants in the greenhouse and in field soils. Arancon and Edwards (2004) and Arancon et al. (2005) showed that solid vermicomposts produced significant suppression of mealy bug infestation (Pseudococcus sp.) on cucumbers and tomatoes, two-spotted spider mite attacks (Tetranychus urticae) on bush beans and eggplants, and aphids (Myzus persicae) on cabbages at low application rates.(Arancon et al. 2007). Yardim etal. (2006) reported the suppression of tomato hornworms and cucumber beetles by solid vermicomposts in the field and in greenhouse experiments.

The use of aqueous extracts from composts and vermicomposts shows potential to suppress a number of pests and diseases on certain plants. This is not surprising because composts and vermicomposts have already demonstrated such suppressions. These extracts, commonly called 'teas', have been fully described in the previous chapters. One of their notable characteristics is that chemical and biological components are largely inherent from the parent material. Their effects on growth of plants and degree of suppression on pests and diseases could vary greatly depending on the characteristics of the parent material. This chapter shows conditions where vermicompost teas successfully suppressed certain pests and diseases. We will also attempt to include the mechanisms behind these suppressions.

Suppression of plant pathogens by vermicompost teas

Preparation of Teas

The greenhouse experimental treatments consisted of three concentrations of aqueous vermicompost extract: 5%, 10% and 20%. Their effects on plant pathogens were compared with those of a deionized water control. The vermicompost aqueous extracts were produced in the Growing Solutions System 10TM Compost Brewing Equipment (Growing Solutions, Inc. Oregon), with a maximum capacity of 37.5L. A 20% aqueous vermicompost solution was prepared by suspending a mesh container with 7.5L of food waste vermicompost in 30L of water. This was extracted for 24h whilst aerating continually. The 20% aqueous extract was diluted to 10% v:v or 5% v:v (tea : deionized water) for use in the experiments. The vermicompost aqueous extracts were used within 24h of preparation to minimize any loss of microbial activity. The 5%, 10% and 20% aqueous vermicompost extracts and a deionized water control were applied as drenches to bring the growth medium at field capacity (Metro Mix 360) at sowing, and at weekly intervals thereafter.

Root Pathogen Experiments

The soil pathogens, crop plants, and pathogen inoculum density, used for each pathogen-plant combination are summarized in Table 4.1. All of the drench treatments were applied to 4 replicate 10-cm diameter pots, each sown with either 8 tomato or 8 cucumber seeds and thinned out to produce 4 plants per pot. 'Teas' were applied as soil drenches (5%, 10%, 20% and a deionized water control), up to the field capacity of the medium, at sowing and weekly intervals thereafter, until harvesting. Pots were arranged on greenhouse benches in a completely randomized design. The numbers of seedlings emerging were recorded. Roots were washed and rated for root pathogen damage severity using a 5 point scale (0 no damage – 5 total damage). The final dry weights of aboveground tissues and roots were determined after oven-drying at 55 0C for 72 hours. Leaf areas were measured on a Licor leaf area meter.

Rhizoctonia
Photo: Norman Arancon

Root Pathogen Experiments Results

Nearly all of the test concentration of vermicompost teas suppressed all root pathogens with the exception of 5% vermicompost tea on *Rhizoctonia solani* inoculation on cucumbers (Table 4.1). The suppression of these pathogens is usually associated better plant growth as measured by growth of foliage such as leaf areas or heights. A typical scenario of increased in plant growth parameters was demonstrated by *Phytophthora capsici* inoculated cucumber seedlings that received vermicompost tea applications (Figure 4.1).

Table 4.1. Suppression of root pathogens on tomatoes and cucumbers using a range of vermicompost teas.

Root Pathogen	Inoculum Density	Suppressive Tea Concentrations	
		Tomato	Cucumber
Fusarium oxysporum	10^8 spores in 5 ml water drenched onto media	5%, 10%, 20%	--
Phytophthora capsici	10^8 sporangia in 5 ml water drenched onto media	5%, 10%, 20%	5%, 10%, 20%
Rhizoctonia solani	0.1% (v:v) Rhizoctonia cultured ground rice inoculum	5%, 10%, 20%	10%, 20%
Pythium ultimum	0.1% (v:v) Pythium potato-soil inoculum	5%, 10%, 20%	5%, 10%, 20%

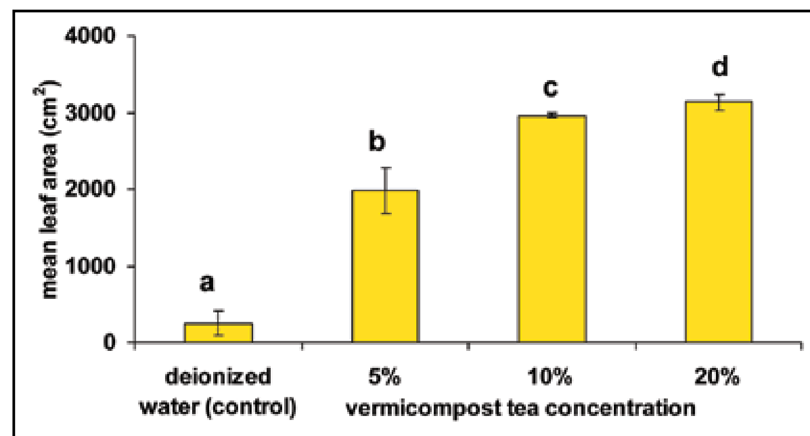


Figure 4.1. Mean plant heights of cucumbers attacked by *Phytophthora capsici* (Means ± S.E.). Columns with different letters are significantly different ($p \leq 0.05$). Plants were grown in MM360 with all needed nutrients supplied (Edwards et al. 2011a)

Foliar Pathogen Experiment

Tomato or cucumber plants were grown in the greenhouse in Metro Mix 360, a soilless sphagnum peat moss-based plant growth media, and inoculated with plant pathogens: *Plectosporium tabacinum, Botrytis cinerea, Verticillium wilt Scleretonia rolfsii.*The range of vermicompost 'teas' and the control deionized water treatments were sprayed on to the crop foliage until run off, one day before, and seven and fourteen days after inoculating plants with the foliar plant pathogens. Greenhouses were maintained at 25 0C and more than 75% relative humidity to provide optimal conditions for infection by the pathogens. The numbers of lesions per leaf and percentage leaf area with disease symptoms were recorded after 14 days. Densities of inoculation for each foliar pathogen are summarized in Table 4.2.

Similar to the patterns of root pathogens suppressions, foliar pathogens were suppressed on tomatoes and cucumbers after applications of teas extracted from food waste vermicomposts (Table 4.2). All of the concentrations: 5%, 10% and 20% suppressed significantly the test pathogens compared with those plants that only received deionized water treatments. The suppression of these pathogens was also associated with increases in plant growth such as those shown by the mean leaf areas of tomatoes attacked by *Botrytis cinerea* and after applications of vermicompost teas.

Table 4.2 .Inoculation densities and suppression of foliar pathogens on tomatoes and cucumbers using a range of vermicompost teas

Folial Pathogen	Inoculum Density	Suppressive Tea Concentrations	
		Tomato	Cucumber
Plectosporium tabacinum	10^4 spores.ml^{-1} water	5%, 10%, 20%	5%, 10%, 20%
Botrytis cinerea	10^5 spores.ml^{-1} water	5%, 10%, 20%	5%, 10%, 20%
Scleretonia rolfsii	10^3 spores.ml^{-1} water	5%, 10%, 20%	5%, 10%, 20%

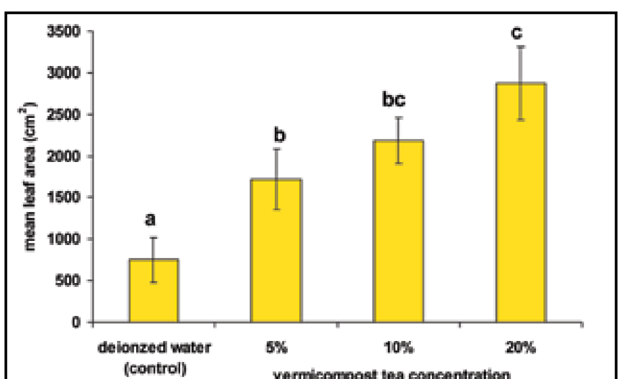


Figure 4.2. Mean leaf areas of tomatoes attacked by *Botrytis cinerea* (Experiment 4) (Means ± S.E.). Columns with different letters are significantly different (p ≤ 0.05). Plants were grown in MM360 with all needed nutrients supplied. (Edwards et al. 2011a)

Suppression of Arthropod Pests and Nematodes

Arthropod Pests

We report significant suppression of plant parasitic nematodes, by soil drenches of aqueous extracts 'teas' produced from food waste vermicomposts, (Edwards et al 2007) and of above-ground foliar pests by soil drenches of aqueous extracts ('teas') (Edwards et al 2010 a and b).

Series 1 Vermicompost teas were prepared using the procedure mentioned earlier from food waste-based vermicomposts, and were used to assess the effects on populations and damage by cucumber beetles *(A. vittatum)* to cucumber plants *(Cucumis sativa)*, the caterpillars of tobacco hornworm *(M. sexta)* to tomato plants (*Lycopersicon esculentum).*The effects of vermicompost tea soil drenches applied at dilutions of 5%, 10% and 20% applied at about 100ml/plant (field capacity) weekly for 2 weeks, were compared with those of deionized water, in the suppression of cucumber beetles and tobacco hornworm. The plants were grown in cages, (40cm x 40cm x 40cm) (0.2 mm mesh) in the greenhouse, and eight cucumber beetles were released on to four cucumber plants per cage or eight tobacco hornworms were released on to four tomato plants per cage.

Series 2 Tomatoes and cucumber seedlings were germinated and grown for 4 weeks in 25cm diameter pots, containing a soil-less growth medium MM 360 and thinned to four plants per pot. They were placed under mesh cages (40cm x 40cm x 40cm) (0.2mm mesh aperture), with one pot containing four plants in each treatment cage. At germination, plants were treated

Striped cucumber beetle photo: ARS Scott Bauer with soil drenches of 5%, 10%, or 20% vermicompost extract or a deionized water control, to bring the medium to field capacity, and thereafter at weekly intervals. A complete Peter's Professional Nutrient Solution was applied weekly to all plants. In each experiment, eight cucumber beetles or eight tobacco hornworms were released onto the leaves of cucumber or tomatoes in each cage (i.e. two pests per test plant). All treatments were replicated four times per pest experiment, in a randomized complete block design. Numbers of pests were counted and damage rated (0-none to 5-total) on days 1, 3, 5, 7, 9, 11, 13 and 14 after the release of pests into the cages.

Series 3 In another series of greenhouse experiments three species of arthropod pest; peach aphids *(Myzus persicae)*, citrus mealy bugs *(Planococcus citri)* and two-spotted spider mites *(Tetranychus urticae)* were caged over tomato and cucumber plants grown in MM360 to which a range of aqueous extracts ('teas') from food waste vermicomposts were applied as soil drenches (Edwards et al 2009a). The designs of the experiments were similar to those used with tobacco hornworms on tomatoes and striped cucumber beetles on cucumbers, except that 100 pests (25 per plant) were released into each cage instead of 8 pests.

Results on Arthropod Pests

The overall effects of the teas on both numbers and damage by all of these pests were dramatic, significant and consistent on both tomatoes, and cucumbers.

Weekly applications of aqueous extracts or 'teas' to tomatoes and cucumbers as soil drenches, had three major effects on the arthropod pests.

Firstly, since the pests in the experimental cages had a free choice to infest any of the test plants, it seems that all application concentrations of the aqueous extracts made both tomatoes and cucumber plants much less attractive for feeding. The highest application concentration of 20% aqueous extract 'tea' had major impacts on the extent of infestation. In a number of the experiments even the 5% extracts made the plants relatively unattractive to the pests.

The weekly soil drenches of vermicompost extracts applied to the soil-less medium in which the plants grew, must also have interfered with the reproduction patterns of the green peach aphids, citrus mealy bugs and two spotted spider mites, since the increased rates of application of aqueous vermicompost extracts decreased the rates of reproduction of all three pests. A typical scenario is shown in Figure 4.3 in which the number of aphids decreased significantly in 5%, 10%, and 20% vermicompost tea applications. The numbers of pests leveled off or decreased particularly in response to the higher application rates of extracts.

Finally, there was consistent evidence that the higher application rates of vermicompost extracts caused the pests to either leave the plants or die, since overall numbers of the pests on the crops decreased significantly with time in response to these higher application rates of vermicompost aqueous extracts. In Figure 4.3, the numbers of aphids decreased with time after application of 10% and 20% vermicompost teas.

Photo: Norman Arancon

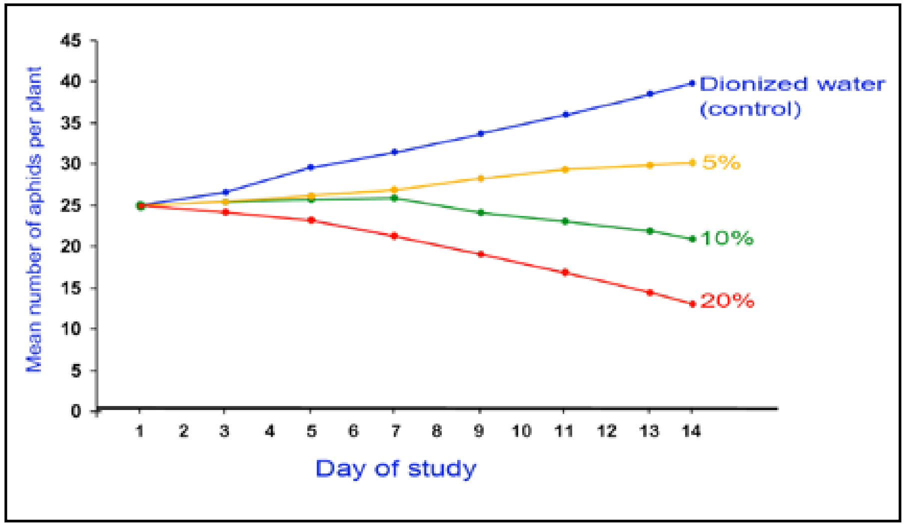


Figure 4.3. Effects of a range of aqueous vermicompost extracts or deionized water (control) on green peach aphid (*Myzus persicae*) numbers on tomatoes. All needed nutrients were supplied. Differences in means were significant at day 14. ($P \leq 0.05$).

Table 4.3. Suppression of striped cucumber beetles, tobacco hornworms, peach aphids, citrus mealy bugs, and two-spotted spider mites on tomatoes and cucumbers using drench treatments of vermicompost teas.

Pest	Host Plant	Suppressive Tea Concentrations
Striped cucumber beetles *(Acalymma vittatum)*	Cucumber	5%, 10%, 20%
Tobacco hornworms *(Manduca quinquemaculata)*	Tomato	5%, 10%, 20%
Peach aphids (*Myzus persicae*),	Cucumber and Tomato	5%, 10%, 20%
Citrus mealy bugs *(Planococcus citri)*	Cucumber and Tomato	5%, 10%, 20%
Two-spotted spider mites *(Tetranychus urticae)*	Cucumber and Tomato	5%, 10%, 20%

Nematode Pests

Series 4 For the nematode experiments, 6-week-old tomatoes and newly-germinated cucumber seedlings were used. Drench treatments of 5%, 10%, 20% food waste vermicompost 'teas' or a control deionized water treatment were applied at transplanting for tomatoes and 7 days after germination for cucumber, and every two weeks thereafter. Ten thousand eggs of *M. hapla* were added to each pot in suspension in deionized water. The eggs were collected from cultures maintained on tomato plants. Thirty days after infestation, soil was removed from the pots to assess the extent of root damage and the numbers of root galls. The washed roots were rated for numbers of root knot galls and the numbers of galls per unit wet weight of roots assessed. The suppression of arthropod pests and nematodes on tomatoes and cucumber are summarized in Table 4.4.

Table 4.4. Suppression of nematodes on tomatoes and cucumbers using drench treatments of vermicompost teas.

Pest	Host Plant	Suppressive Tea Concentrations
Nematodes *Meloidogyne hapla*	Tomato	5%, 10%, 20%
Nematodes *Meloidogyne hapla*	Cucumber	10%, 20%

Nematode Pests Results

All of the three application rates of food waste vermicompost teas increased the shoot weights of tomato plants significantly ($p \leq 0.05$), compared with the deionized water control. The three vermicompost 'tea' application rates all increased mean leaf areas significantly ($p \leq 0.05$) (Figure 4.5) compared with the deionized water control. The growth of tomato plants inoculated with M. hapla and treated with a range of vermicomposts or 20% thermophilic compost are illustrated in Figure 4.6. The differences in tomato plant growth between treatments, especially in response to the vermicompost 'teas' were spectacular

The higher the concentration of vermicompost tea the less was the response of the tomato plant to the nematode; which demonstrates clearly the dramatic suppression of the nematode populations and damage by the vermicomposts..

The numbers of nematode root knot galls on tomato plants in response to the vermicompost 'tea' applications are illustrated in Figures 6. The suppression of the nematode galls in response to application of the vermicompost 'teas' was extremely dramatic and significant (p

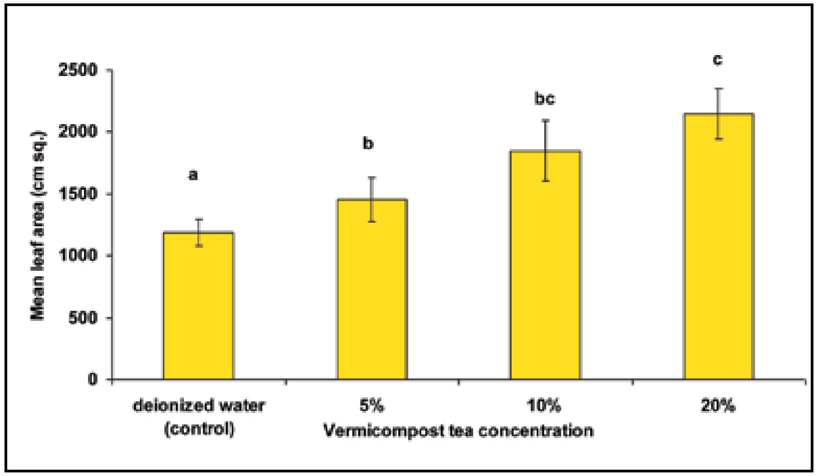


Figure 4.4. Mean leaf areas of tomato plants grown in MM360 and received all needed nutrients infested with Meloidgyne hapla and treated with soil drenches of vermicompost 'teas' (mean ± S.E.) columns with different letters significantly different ($p \leq 0.05$)

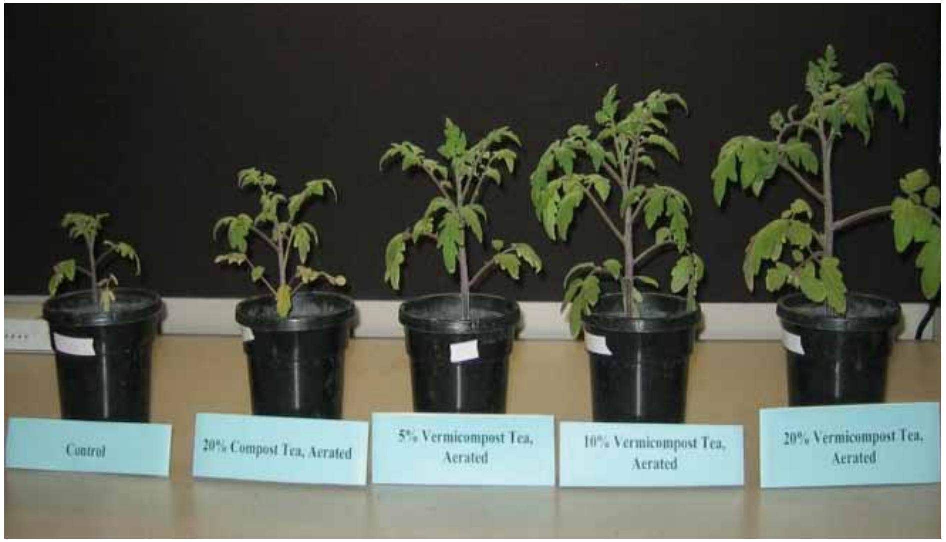


Figure 4.5. A comparison of tomato plants infested with Meloidogyne hapla and treated with thermophilic compost 'teas' or a range of food waste vermicompost 'teas'. Plants were grown in MM360 with all needed nutrients supplied. *Photo: Norman Arancon*

≤ 0.05) and led to considerable increases in tomato growth. Clearly, the effects of the food waste vermicompost teas on the suppression of *M. hapla* damage were dramatic, and so was the suppression of the number of galls on the tomato roots which are illustrated in Figure 4.6.

Since the roots of the plants grown with ionized water were so small compared with those receiving vermicompost teas the data were expressed as numbers of galls per gram of roots (wet weight) but the size of the roots is a more relevant index of the overall damage.

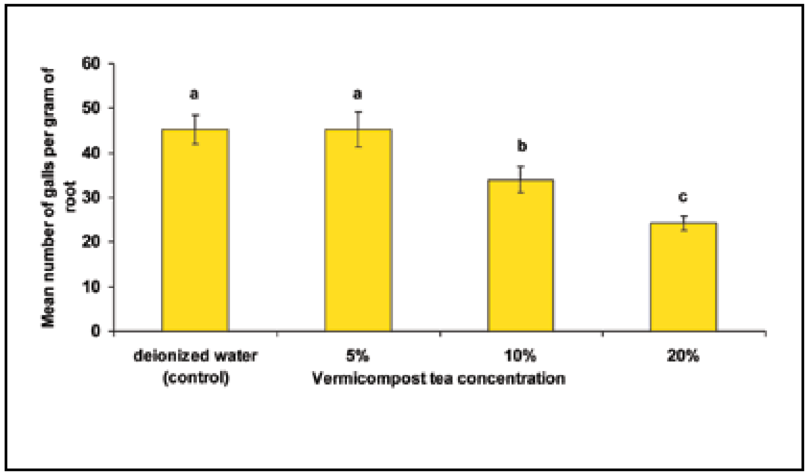


Figure 6. Mean numbers of *Meloidgyne hapla* galls (mean ± S.E.) on tomato roots infested with the nematodes and treated with soil drenches of vermicompost 'teas' columns with different letters significantly different (p ≤ 0.05). All plants grown in MM360 and received all needed nutrients.

The numbers of galls on the cucumber roots (Figure4. 7) were decreased significantly (p ≤ 0.05) by the 10% and 20% application rates of food waste vermicompost 'teas' compared with the water control (p ≤ 0.05). Similarly, only the 10% and 20% 'tea' applications increased mean leaf areas. Only the 10% and 20% food waste vermicompost 'tea' applications increased cucumber leaf areas and fresh shoot weights significantly (p ≤ 0.05). However, all three applications of food waste vermicompost 'teas' increased fresh root weights significantly compared with the water controls (p ≤ 0.05). In terms of the heights of the cucumbers plants (Figure 18) all of the three application rates (5%, 10%, and 20%) increased the mean heights of the cucumber plants significantly.

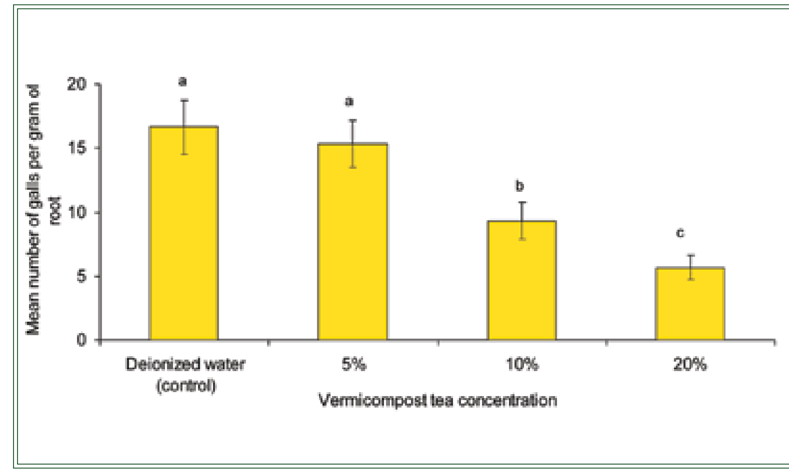


Figure 7. Mean numbers of Meloidgyne hapla galls (mean ± S.E.) on cucumber roots infested with the nematode And treated with soil drenches of vermicompost 'teas' or deionized water grown in MM360 and received all needed nutrients

Mechanisms of Suppression

Several theories have been proposed to explain the tolerance of some crops against infestation of pests and diseases. They usually result in complex interactions between the major factors involved the growth and development of plants. These include availability of mineral nutrition and its sources, physiological and morphological changes of plants as affected by mineral nutrition and the eventual changes of the feeding behaviors of the pests and pathogens infesting the plants. The fecundity of these pests and pathogens could also be affected by the changes in the diversity and population of other microorganisms resulting from the addition of a variety of sources of organic matter.

The production of 'teas' from vermicomposts can multiply both soil-dwelling and epiphytic microbial populations that can suppress plant pathogens. Several mechanisms of specific suppression by vermicompost and vermicompost 'teas' have been proposed, including (a) destruction of pathogen propagules; (b) prevention of propagule germination; (c) antibiosis; (d) hyperparasitism; (e) competition for nutrients; or (f) competition for infection sites (Stone et al., 2004). In practice there is probably is a combination of multiple effects, including competition for nutrients, antibiosis, extracellular enzymes and parasitism, acting directly on the pathogens in the bulk soil or the rhizosphere, or indirectly through host-mediated induced resistance (Noble & Coventry 2005). The other type of suppression is a general suppression which cannot be linked any individual organism. A wide range of aerobic organisms may be involved, and a range of population effects may lead to suppression of plant pathogens. However, it is difficult to determine the exact suppression mechanisms since a compost, or vermicomposts, represents a "microbial community structure rather than a single species" (Boulter et al 2002). Effective disease antagonists that may occur in composts include Trichoderma hamatum, Flavobacterium balustinum, Pseudomonas aeruginosa, P. fiuorecens, P. putida, P. stutzeri, Xanthomonas maltophilia, Janthinobacterium lividum, Enterobacter cloacae, E. agglomerans, Bacillus cereus, B. mycoides, and B. subtilis (Hoitink and Fahy 1986, Dowling et al 1996, O'Sullivan & O'Gara 1992, Shanahan et al 1992). Several of these microorganisms can induce systemic resistance to plant disease (Han et al 2000, Krause et al 2003). Alfano et al (2007) demonstrated that systemic resistance induced in tomato by Trichoderma hamatum 382 was linked to the up-regulation of genes for several different stress-related proteins. A diverse array of bacteria and several fungi have been identified that can significantly suppress pathogens. Some Suppressive properties include secretion of: hydrolytic enzymes that attack pathogen membranes (e.g. chitinase, protease, β-1,3, glucanase); iron-chelating siderophores that limit the availability of iron for the growth of pathogens; cyanide; and antibiotics (Mazzola 2002).

It is also important to note that vermicomposts are produced through mesophilic rather than thermophilic process which may offer a totally different set of microbial community than those of traditional composts. Hence, their suppressive qualities of these materials and its aqueous extracts may differ within specific crops and pests and would surely require further investigation. Compost qualities are also dependent largely on the source of organic material from which they are produced and it is inevitable that the suppressive properties can also vary.

Decreased infestations of insects on plants are usually based on either differential availability of mineral nutrients to plants or on changes in the balance of available nutrient elements, which could affect aspects of plant morphology and physiology in ways that could render plants more resistant to pest attacks (Patriquin et al., 1995; Fox and Macauley, 1977; Prestidge and McNeill, 1983). Some of the changes in plant characteristics affected by organic or inorganic nutrition, are their growth patterns such as the onset of senescence, thickness and degree of lignification of the epidermal cells, sugar concentrations in the apoplats, amino-N in phloem sap, and levels of secondary plant compounds (Patriquin et al., 1995). Plants grown in soils with high levels of N resulted in larger infestations of cabbageworms, diamondback moths and thrips, promoted faster development of aphids (Dixon, 1969) and production of larger lepidopteran larvae (House, 1965). Fox and Macauley (1977) suggested that amounts of N in a plant can often be correlated positively with the extent of insect feeding. Conversely, inadequate nitrogen availability can increase rates of consumption of plant tissues by insects, thereby causing even more damage to crop plants (Hamilton and Moran, 1980). Products of nitrogen metabolism, such as amino acids have also been linked to increased insect pest attacks on plants. For instance, large amounts of amino acids stimulated the growth and fecundity of some herbivorous insects (Prestidge and McNeill, 1983). Wilson and Stinner (1984) suggested that decreased infestations by aphids were due to poor assimilation of ureide N by pests. Additionally, variations in the nutritional status of plant tissues other than N, might influence pest resistance, or result in increased susceptibility to insect attacks, due to deficiencies of K, Ca, Bo, Zn and Si (Patriquin et al.,1995).

The use of organic amendments provide a more balanced and better timed

Tomato with *Rhizoctonia* Photo: Norman Arancon source of nutrition for plant growth, through gradual decomposition of the organic matter by microorganisms, and slower mineralization rates of nutrients that it contains (Pascual et al., 1997; Zink and Allen, 1998; Patriquin et al., 1995). Vermicomposts, as an organic amendment, can usually provide plants with a balanced source of nutrients and influence the composition and physiology of plants. Our results demonstrate that use of vermicomposts in the potting medium had considerable influences on the intensity of attacks and damage by aphids, mealy bugs and imported cabbage butterfly. Vermicomposts teas could have provided some essential nutrient elements, that are not available in inorganic fertilizers, and these could either have increased the plants resistance to pests or made the plants less palatable to the pests.

A number of plant metabolites have been identified as compounds that can deter pests and pathogens from infesting plants. The enzyme chitinase has been reported to be present in vermicomposts (Hahn 2001) and it is feasible that this could affect arthropod pest molting. However, this enzyme has never been reported in the literature to have any effects on pests, although it does appear to have some influence on plant pathogens. There is unlikely to be a mechanism by which microorganisms might be taken up into the tissues of plants and could thereby influence arthropod pest feeding. Hence, the most likely way in which vermicomposts and similar organic materials may inhibit attack by arthropod pests on the foliage and fruits of crop plants, is to change the arthropods' feeding responses. It is well known that phenolic substances are distasteful to secondary invertebrate decomposers in soil systems and inhibit the breakdown of dead and decaying plant materials (Edwards and Heath1963; Heath and Edwards1964). Asami et al. (2003) reported that the total phenolic contents were significantly higher in marion berries, strawberries, and corn plants grown organically than in those grown with inorganic fertilizers. An endogenous phenoloxidase has been obtained from an earthworm, *Lumbricus rubellus,* that is sometimes used to produce vermicomposts. This phenoloxidase can bioactivate compounds to form toxic phenols, suchasp-nitrophenol (Parketal.1996). Polychlorinated phenols and their metabolites have been reported from a range of soils containing earthworms (Knuutinen et al. 1990). Vinken etal.(2005) found that monameric phenols could be absorbed by humic acids in the gut of earthworms. In another study, Koul (2008) identified phenolics as insect anti-feedants in a review on these and other chemicals. It has also been shown that sprays of phenols and phenolic acids extracted from gingko plants were as effective in controlling attacks by caterpillars, as the use of several pesticides approved for use against these pests(QiTian 2004). Haukioja etal.(2002) reported that phenolics in plant tissues decreased the rates of consumption of tissues by a geometrid caterpillar *Epirrita autumnata*. These results all point to the probability that water-soluble phenols, extracted from the vermicompost during the brewing process and taken up by plants from soil receiving drenches of vermicompost aqueous extracts, is the most likely mechanisms by which vermicompost aqueous extracts can suppress pest attacks. A similar mechanism would account for the suppression of arthropod pests by solid vermicomposts (Arancon and Edwards 2004; Aranconetal.2005).

Brew Master -5

Faith, Tio and Keola Tuipulotu
Tuipulotu Farm
Ho'olehua, Hawaii

Type of Operation: Certified Organic
Years using compost tea: 9 weeks
Apply tea to: Papaya

Source compost

Compost type: Vermicompost
Compost source: Wonder Worm (OMRI listed

Extraction

Method: Aerated, Hakko pump, HK 80
Ratio by volume:1:20
Supplements: We use 4 cups of worm casting, blood meal, or fish bone meal to 5 gals. of water and 2 tablespoons molasses and kelp to 5 gal. of water.

Application

Method: Dosatron drip irrigation lines
Coverage: 50 gal/acre
Frequency: Once a week and usually after harvest

Observed benefits

I don't know if I'm imagining this but, we started using compost tea the 1st week, 2nd week, 3rd week then stopped the 4th week and the powdery mildew infested the 1 acre. We started applying compost tea in the 6th, 7th, 8th, and 9th week and the powdery mildew hasn't come back into the field.

Advice

Gather as much information as you can and see what works best for you and your crops.

Frequently Asked Question:

Does it Work?

Researchers: B. S. Sipes, G. Taniguchi, and T. Radovich (citation)

Not always, and there may be unexpected results.

Heart rot caused by Phytophthora nicotianae var. nicotianae and other species, is a serious and widespread disease encountered in the production of pineapple. Control is achieved by moderating soil pH, providing drainage, and the use of pesticides. Although Aliette is an effective, environmentally safe, and inexpensive pesticide, alternatives are desirable. The objective of this research was to determine the efficacy of vermicompost teas and acibenzolar-S-methyl (BTH) in protecting pineapple from heart rot caused by P. nicotianae var. nicotianae.

Materials and Methods

A test was established in a P. nicotianae var. nicotianae nursery. Treatments were an untreated control, drenches of aqueous extracts of vermicompost (equal to 2.3 mt/ha, 10:1 v/v water:compost, delivered in 500 ml/crown) with (activated) and without microbial enhancer (see chapter 2), a BTH (100 ppm) dip, and a fosetyl-Al (Aliette 3 g/l) dip. Each treatment was replicated 10 times. Plots were irrigated immediately after planting and then weekly. Plant death was recorded weekly beginning 3 weeks after planting and continuing through to 12 weeks after planting. Cumulative plant death was analyzed for variance. Where appropriate, treatment means were separated with a Waller-Duncan k-ratio t test (k=100).

Table B Pineapple crown death (percent) from heart rot 12 weeks after planting in two low-acid cultivars treated with vermicompost teas. as SAR inducer (BHT) or Aliette.

	Untreated	Activated Tea	Tea	BTH	Aliette
73-114	59 a	33 b	61 a	34 b	14 c
73-50	68 x	66 x	55 y	53 y	24 z

Numbers in a row with the same letter are not different (P>0.05).

Results

Compost tea had inconsistant effects on pineapple crown survival. Heart rot in the activated and unactivated vermicompost tea treated crowns was similar to the untreated control in 73-50 plants (Fig. 1 and Table 1). The activated vermicopost tea treatment was similar to the BTH treatment in hybrid 73-114 (Fig. 2) whereas the unactivated tea behaved similar to the untreated control (Fig. 2). The vermicompost teas did not control heart rot, especially in 73-50. BTH provided early control of heart rot and gave lower levels of plant loss compared to the untreated pineapple. Vermicompost teas did not provide sufficient control of heart rot in pineapple. BTH may be useful when disease pressure is not great or environmental conditions are not favorable to heart rot. Aliette continues to provide excellent control of heart rot.

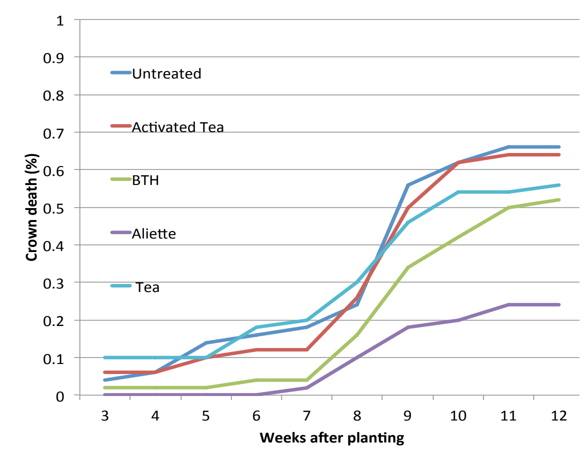


Figure B1. Death of pineapple hybrid 73-50 from *Phytophthora nicotianae.*

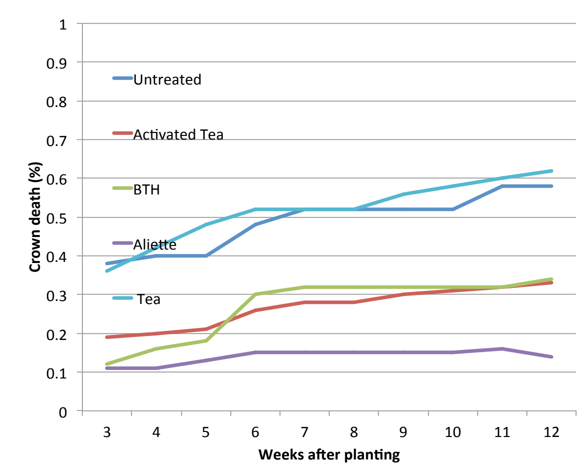


Figure B2. Death of pineapple hybrid 73-114 from *Phytophthora nicotianae.*

Brew Master #6

Erin Lee,
Hualalai Resort, Kailua-Kona, Hawaii

User Profile
Type of Operation: Resort
Years using compost tea: 12
Apply tea to: Ornamental plants: trees, particularly if they seem compromised; interior quality palms and foliage; turf, groundcovers, and shrubs.

Source compost
Compost type: Thermophilic
Compost source: On-site
Compost feedstock: Foliage, grass clippings, leaves, chipped branches

Extraction
Method: Aerated, Growing Solutions 100 gal
Ratio by volume: 50: 1
Brewing time: 24 hours
Supplements: Always use a catalyst at recommended rate, sometimes use molasses 1 qt/100 gal

Application
Method: Drench, foliar spray
Coverage: 100 gal/15,000 sq ft
Frequency: We brew and use daily, rotating areas of application.

Observed benefits
We observe increase plant vigor, ability to withstand environmental stress and better resistance to insect infestations.

Advice
Keep doing it; make compost brewing a behavior. Keep compost dampened during storage to keep the microbial organisms active and keep the brewing machine clean by thoroughly hosing down all parts. We use compost tea as an added amenity in addition to our fertilizing and IPM program for our custom estate and residential landscaping contracts. We also use it to establish new plantings in our hotel and residential properties. *Photo: Erin Lee*

Chapter V - History, Trends, and Outlook; An industry perspective

Michael Alms

History

Compost tea has a long history and has been used in many different forms. Almost every major agricultural region in the world extracted compost into a liquid for the same reasons we do today; to apply the beneficial components of compost with less labor, less energy and more readily available (bio-available) nutrients and organic compounds than the solid material. There are historical references to the use of liquid compost in leading agricultural centers such as Roman, Greek, Egyptian, Mayan and Polynesian cultures. While production methods varied depending on the climate, compost feed stocks, or crops, the end goal was the same; These early adopters were providing a biologically rich and nutrient dense solution for their crops.

Fast forward to modern times, in January 1997 the compost tea industry was officially formed in the United States. Shifting from a wide range of on-farm and home-made compost extraction devices to commercially produced machines; the compost tea industry was underway. The first machines to enter the market were officially branded as Microb-Brewers and were produced, and marketed, by a small company in Oregon called Growing Solutions Incorporated. Mr. Karl Rubenberger owned the US Patent for these units and named Growing Solutions as the North American manufacturing licensee. The first unit to be manufactured and released to the market was the Microb-Brewer 50g, a 50 gallon compost tea machine. Soon to follow were 12 gallon and 500 gallon versions designed and manufactured under the same patent.

The Microb-Brewer quickly moved into many sectors of agriculture including small and large scale farming operations, greenhouse and horticulture production facilities and some early adopters within municipal greenspace markets. As with any emerging technology market, new competition was arriving on the scene offering various iterations of the original Microb-Brewer. At this stage, the Microb-Brewer and the new arrivals were primarily designed as re-circulation devices and classed as aerobic compost tea machines. Re-circulation was utilized to bring air in contact with the tea solution and ultimately diffuse oxygen throughout the holding tank.

The first commercial compost tea brewers, manufactured by Growing Solutions, became available in 1997. Early brewers primarily used recirculation to aerate the tea solution.

2001 / New Technology

2001 saw a revolutionary design change in commercial brewers. Aeration by recirculation gave way to aeration by bubble diffusion. This technology had been developed for the wastewater treatment industry 25 years prior and proved to be a very suitable method to provide both oxygen and thorough mixing, by way of air bubbles. Growing Solutions integrated this technology into their patented compost tea system design. Within a year, various versions replicating Fine Bubble Diffusion appeared on the market driving commercial competition and further establishing a basis for a new industry.

(Photo courtesy of Growing Solutions)

Microbial Nutrient Sources

Another area of new and constantly evolving idea, are the use of nutrient sources, or additives, as food for the reproduction of microorganisms during the compost tea extraction process. While the science community is still adjourned on the matter, the private sector continues to forge ahead with their own set of field experiments using various ingredients to produce the ultimate compost tea. Currently, there are three basic schools of thought in regards to the use of supplemental foods:

- No additives whatsoever. The compost tea is simply produced as a pure extraction of the source compost without any additional food ingredients.
- Food resources used are in the form of simple sugars such as molasses, pure cane sugar, etc.
- Food resources used are comprised of complex carbohydrates such as starches, botanical extracts, etc.

This is an area of controversy within the science community, regulatory agencies and the private sector. The primary concern is food safety revolving around the use of simple sugars as food resources for the microbial population, as this could potentially promote reproduction of human, or plant pathogens. As the industry evolves, safety protocols and standards will come into place allowing for quality compost tea production without risk to people or the crop.

Compost

Regardless of the compost tea machine you are using, the source compost is the number one driver of the final compost tea quality. How well engineered the compost tea machine is – whether commercially produced or home-made, or how highly complex your food resources may be – the end result of compost tea always is directly correlated to the source compost quality. See page xx in chapter 1 for details on selecting the source compost.

(Photo courtesy of Growing Solutions)

Markets

In 1997 the primary use of compost tea was for agricultural crops, mainly in the young and burgeoning organic industry. Today the use has spread into many new markets, some of which were unexpected. Compost tea is used in a wide range of applications including municipal parks, sports fields, schools and botanical gardens as a viable alternative to conventional fertilizer programs. While not all of these market have verifiable scientific evidence pertaining to compost tea's value, there is a wealth of supporting anecdotal evidence in favor of its use.

Clockwise from top: Keyser Stadium, San Francisco; cyclamen, Bellingham, WA; pineapple, Maui, Hawaii; Harding Golf Course, San Francisco. *(Photos: cyclamens courtesy of Sound Horticulture, other photos courtesy of Growing Solutions)*

Application Methods

As the industry continues to expand in the aforementioned sectors, the ability to apply compost tea cost-effectively, with successful results, is a compelling issue to address. The biggest challenge our industry faces is the re-engineering of application equipment that was originally designed for soluble chemicals and fertilizers. While this is certainly a surmountable task, it is a significant shift in traditional tooling. A combination of input from end-users in the field, application equipment suppliers and manufacturer engineering teams all need to work together to offer cost effective solutions that will perform in the field.

Methods shown from top to bottom: greenhouse sprayer; boom sprayer; center pivot; nozzle options; hand sprayer. *(Photos courtesy of Growing Solutions, photo lower right: Erin Lee)*

Future Outlook

Our industry has many success stories across a wide range of compost tea uses. Home gardeners to 5000 acre farms have realized tea's benefits. Attributes of compost tea include optimum delivery of micronutrients and bio-available organic compounds. Additionally, a host of beneficial microorganisms found in quality compost tea provide the mechanics of creating soil structure that results in greater oxygen exchange and increased water holding capacity.

Compost tea production is a relatively young industry. Researchers are just now investigating the mechanisms that provide the disease suppression and growth enhancement that growers have observed. The availability of micronutrients and organic compounds is a compelling reason to implement a compost tea program. Please see chapters three and four for more information on this research.

Looking forward, three new applications for compost tea are of particular interest due to their direct impact on the environment and food quality. These include soil remediation, water conservation and nutrient-dense food production.

Areas for Further Research

Soil Remediation

Well-structured soils promote root health and active growth by maximizing water and oxygen availability and minimizing compaction, which slows root penetration. Biological activity of microorganisms, contributes significantly to soil aggregation. The biological fraction of compost tea to improve soil profiles is an area that has been identified for increased investigation.

Water conservation

It has generally been accepted by the science community that increasing soil organic matter has a positive correlation with water holding capacity. While historically the use of high quality compost has offered this benefit as a soil amendment, there are reports within the industry of similar results with the use of compost tea.

Food quality

The use of compost tea in food production systems can improve the nutrient status of the plant. This in turn can impact the primary and secondary metabolites that contribute to human nutritional value and flavor.

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Suppliers

This listing includes suppliers that may be of interest to growers in Hawaii. More suppliers may be available within the community so check with farmers in your area.

Compost Tea Brewers

Greater Earth Organics
N2210 Brothertown Beach
Chilton, WI 53014
920-251-0333
www.GreaterEarthOrganics.com

Keep It Simple, Inc.
12323 180th Ave. NE ·
Redmond, WA 98052-2212
1-866-558-0990
www.simplici-tea.com

Growing Solutions
1702 W. 2nd Ave., Suite
B Eugene, Oregon 97402
541.343.8727
www.growingsolutions.com

Living Soils Organics
P.O. Box 107
Paauilo, HI 96776
808-443-9232
www.livingsoilsorganics.com

Diagnostics

Agricultural Diagnostic Service Center
University of Hawai'i at Manoa
1910 East West Road
Sherman Lab 134
Honolulu, HI. 96822
808- 9566706

Microbial Matrix Systems, Inc.
33935 Hwy 99E, Suite B
Tangent, OR 97389
Phone: 541-967-0554
www.microbialmatrix.com

Soil Foodweb Oregon, LLC
635 SW Western Blvd
Corvallis OR 97333
541 - 752 - 5066
www.oregonfoodweb.com

Compost Producers

EKO Compost (Use biosolids)
P.O. Box 1065
Puunene, HI 96784 1
808-572-8844

Heart and Soul Organics
6220 Koolau Road,
Kilauea, HI 9675
(808) 823-1007

Maui Earth Compost, Inc
808-877-0403
www.mauiearthcompost.com

Hawaiian Earth Products
(Kapa'a Quarry)
101 Kapaa Quarry Road
Kailua, Hawaii
Phone: (808) 261-5877

Kauai Nursery and Landscaping,
3-1550 Kaumialii Hwy
Lihue, Kauai, Hawaii 96766
808(241)5165
www.kauainursery.com

Vermicompost Products and Supplies

Hawaii Rainbow Worms
905 Hoolaulea Street
Hilo, HI 96720
(808) 937-2233
www.hawaiirainbowworms.com

Joy of Worms
Wilma Nakamura
9220 Kula Highway
Kula, HI 96790
(808) 876-0911

Darryl Kalua & Sons
Pahoa, Hawaii
Phone: (808) 982-6917
dmkalua@hawaiiantel.net

Olomana Gardens
41-1140 Waikupanaha St
Waimanalo, HI 96795
(808) 259-0223
http://www.olomanagardens.com

Waikiki Worm Company
234 Ohua Ave. #118
Honolulu HI 96815
Phone: (808) 382-0432
http://www.waikikiworm.com/

Wiki Wiki Worm Ranch
Kalaheo, Hi 96741
phone: 639-2016 www.wikiwikiwormranch.com/

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Compost Tea

Farmers have long known the benefits of compost application for plant growth and health. While many growers would like to spread compost frequently, they are limited by availability, costs and the labor required.

Compost "tea" extracts the beneficial components of compost into a water solution. It is often presented as either a "Silver Bullet", or conversely, "Snake Oil." Like most other traditional agricultural inputs, compost tea is neither. There is a lack of clarity regarding the actuak benefits and limitations of compost tea. These gaps in our knowledge limit the efficacy of compost tea applications on the farms that currently employ this strategy, and seriously restrict the extension and adoption of compost tea technology to other farms that want to improve the sustainability of their operations.

The book provides an overview of current research and practices for the production and use of compost tea in tropical climates. This book was written for commercial food producers, home gardeners and agricultural professionals.

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