Compost Tea

Literature review on production, application and plant disease management

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Compost tea Literature Review

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1. INTRODUCTION AND OVERVIEW

Compost tea is a liquid extract made by steeping compost in water using a variety of preparation methods (Scheuerell 2002, Ingham 2005) . Historically, home-made brews were prepared by suspending a bag of compost in a container of water for up to 14 days to extract nutrients that when applied to plant promotes health and vitality. This type of brewing practice is call "passive" or Non-aerated Compost Tea (NCT) and has been practiced for centuries. More recently, compost tea has been brewed in large-scale mechanized systems for shorter periods of time and often supplemented with oxygen, nutrients, and microbial starter cultures to enhance the biological activity of the tea (Scheuerell 2004; Ingham, 2005, Naidu 2010). This type of brewing technique is referred to as Aerated Compost Tea (ACT). ACT has become more popular than non-aerated Compost Tea, as an alternative to chemical fertilizers, pesticides and fungicides. It is used by organic farming communities, golf course managers, municipalities, and park and recreation facilities as part of an integrated pest management (IPM) practice. Benefits of ACT such as healthy soil, better plant vitality and disease suppression are reported by some users and advertized by the manufacturers of compost tea.

Research on compost tea technology began in 1980's, but field trials comparing the brewing methods are scarce. The majority of studies to date have focused on plant disease and suppressive ability of compost tea. There is evidence that some plant diseases have been partially suppressed by application of compost tea (Scheuerell 2002, and Brinton 2005), while in other studies, suppression has been highly variable between different batches batch preparations (Hoitink 2003, Scheuerell 2005, Scheuerell 2006). Potential problems such as pathogen or chemical contamination of crops by application of compost tea have also been documented in recent scientific studies (Ingram 2007, Brändli 2006).

This review summarizes some of the current research on compost tea, with emphasis on:

a) Brewing methods
b) Factors affecting compost tea production and its quality
c) Application methods
d) Benefits of Compost tea (suppressive effects, growth simulating effects)
e) Potential problems
f) Recommendations for Compost tea users and IPM managers

This report is not an attempt to cover all the research on Compost Tea or compost tea additives. Instead, the few major studies that have been peer reviewed are cited. References to organizations or publications on the internet are also included in this report. The peer reviewed citations are clearly identified by the first author's name and date of publication throughout the document, with details provided in references under section 7.

1.1 Definition of terms

Composts — Organic-rich soil amendments are made primarily from yard waste, food waste, manure and biosolids. Yard waste includes organic waste from lawns and gardens, such as grass, leaves, and twigs. Food waste is similarly comprised of fruit and vegetable trimmings and kitchen preparation residuals. Biosolids are nutrient-rich organic materials resulting from the treatment of sewage sludge. Manure, an agricultural waste, can offer multiple beneficial uses including nutrients for crop production and organic matter to improve soil properties.

Compost Tea: A term used interchangeably with "*Watery Fermented Compost Extracts*", "*Compost steepage*", "*Organic Tea*" and "*Compost leachate*" to define water-based compost preparations. The term does not distinguish between the productions methods (Scheuerell 2002).

Amended Extract: Compost extracts that have been fermented or brewed with the addition of nutrients, or extracts supplemented with specific beneficial microbes before application (Scheuerell 2002,).

Vermicompost Extract — Extract of composting or end-product of the breakdown of organic matter by various species of earthworm. Worms are very efficient at breaking down food scraps and are sometimes used in a composting process, known as vermicompost (Allison L. H. Jack 2010).

Beneficial Microbes: Natural microorganisms that live in healthy soil can increase plants health and vitality by variety of mechanisms (Haas and Défago, 2005) such as:

i. direct association with roots;
ii. breakdown and release of minerals from organic matter to increase nutrient uptake in plants;
iii. parasitizing harmful or disease causing microorganisms or;
iv. suppressing growth, or activity of harmful disease causing microorganisms through other interactions such as production of antibiotics or other chemical inhibitors.

Predominant classes of beneficial microbes include bacteria and fungi, protozoa and nematodes.

2.0 COMPOST TEA BREWING METHODS

Compost Tea is made by two brewing methods:

Non-Aerated Compost Tea (NCT): The traditional method involves a "passive" brewing process where no oxygen input is required. This method produces Non-aerated Compost Tea (NCT). NCT relies on the use of stable compost without sugar additives, under low oxygen with occasional stirring of the extract. The term anaerobic (no oxygen) has been used to refer to NCT in some recent literature. However, since the process occurs in an open fermentation vessel, the term anaerobic- does not accurately define this brewing method. Average NCT brewing period is 14 days.

Aerated Compost Tea (ACT): A more recent approach adopted by compost tea brewers involves an "active" process which relies on the use of an aerator to oxygenate the mixture during the fermentation process, thereby producing Aerated Compost Tea (ACT) in a shorter brewing time ranging from 12 hrs to 3-days. Often, nutrient additives and fermentation products rich in microorganisms are added during the brewing process to increase the beneficial microbes' concentration in the brew.

Both brewing techniques can be adopted for small backyard home brew or a large production scale.

2.1 Compost Tea Supplies and Manufacturers

Limited supplies are required for the non-aerated compost tea production. The passive brewing method is simple, inexpensive and requires primarily a good grade of compost, and a container to brew the tea with occasional stirring. In contrast, there are a growing number of suppliers who provide equipment such as specialized containers, pumps and tubing and a variety of nutrient additives and microbial supplements such as "Effective Microorgamism" or EM•1® for brewing and application of the aerated compost tea. In addition, ready to use compost tea is available from large scale manufacturers. Some of these major suppliers & manufacturers include:

Nature' Solution http://www.nature-technologies.com
Growing Solutions Inc. http://www.growingsolutions.com
Malibu Compost Biodynamics http://malibucompost.com
Rittenhouse http://www.rittenhouse.ca
Soil Soup, Inc. a registered trade mark of Microbial Magic http://www.soilsoup.com
Sustainable Agricultural Technologies, Inc. http://www.composttea.com
Teragenix-Effective Microorganisms Distributor in US- http://www.teraganix.com/

3.0 COMPOST TEA QUALITY

3.1 Production Process

The brewing or fermentation process refers to the process of steeping compost in water at a constant temperature and for a defined period of time whereby nutrients and microorganisms from the compost source are extracted. Microorganisms convert insoluble nutrients into available nutrients during the brewing process. Soluble nutrients in turn promote growth of diverse community of organisms in the tea. There is little data in scientific literature that directly compares compost tea production processes (Scheuerell 2006). However, available data suggests that both aerated and non-aerated compost tea can be inconsistent from batch to batch. The inconsistency has been associated with to a number of factors

that affect the production process [(Ingham 2005, www.soilfoodweb.com), (Ingram 2007), (Scheuerell 2006), (Hsiang 2007)]. These factors include:

- Compost Grade
- Compost to water ratio
- Brewing time
- Fermentation nutrients
- Microbial Supplements
- Aeration
- Filtration and dilution before application

Each of these factors is described below with major differences and similarities between ACT and NCT production processes outlined in Table I.

Compost Grade

The organic ingredients or *feedstocks* that make up the mature compost include animal manure, landscape and agricultural plant material, biosolids and food waste. Each has characteristics that influence the quality of the mature compost (Scheuerell 2002). Some research suggests composition of microgoranisms in compost depends on the feedstock. For example, carbon rich feedstocks (e.g. dry leaves, sawdust, wood chips, shredded newspaper), produce a compost with a higher fungal content while nitrogen rich feedstock (hay weeds, coffee grounds, herbaceous material and manures) produce compost with higher bacterial content (Scheuerell 2006). Similarly, vermicompost is used as an ingredient in many compost tea recipes. This compost is typically the highest in available nutrients. Therefore selection of compost regardless of the production method depends on its intended use.

Mature Compost should be stable and free of pathogens. Research at Wood Ends Laboratory indicated that many immature types of compost are available on the market, with little or no quality testing behind them (Brinton 2004). The immature compost is less stable and may harbor pathogens. In California, commercial composters are required to meet specific regulatory requirements on the compost process itself that protect health and safety. The most important indicators of compost stability are the temperature cycles in composting process and the carbon to nitrogen content (C: N). The C: N ratio decreases as compost becomes more mature or stable (Noble 2005). Calrecylce.org has published quality standards for finish compost that can be accessed at
http://www.calrecycle.ca.gov/organics/products/Quality/Needs.htm

Compost to water ratio

According to published studies, ratio of compost to water (volume: volume) tend to vary for each production method. For NCT, the majority of studies use a 1:3-1:10 ratios (Scheuerell et al., 2002). For ACT, the ratio depends on type of equipment and is usually suggested by the compost tea equipment suppliers. Potable water that is free of chlorine or chloramines is recommended for making compost tea or any dilution thereof regardless of the production method. Chlorine or chloramines are added to potable water as a sanitizing agent(s); when present in the water, these chemicals can inhibit growth and propagation of microorganisms during the brewing process.

Brewing time

Several studies on disease suppression properties of NCT have indicated that NCT brewing time of 8-16 days is optimal fermentation time for any level of disease control (Scheuerell 2002). It has been proposed that the longer brewing period promotes greater amount of nutrients to be extracted from the compost and enables accumulation of antibiotics that activate natural plant defense responses and help in disease suppression (Scheuerell 2003).

A significant advantage reported by the manufacturers and the users of ACT is the short brewing time of 18 hrs to 3 days which makes the tea readily available. It has been proposed that that optimal brew time of 18-24 hours coincides with maximum activity of microbial population in the tea (Ingham 2005).

Nutrient supplements

Nutrients such as kelp, fish hydrolysate, molasses, and humic acid are added as catalysts or microbial starter (Naidu 2010, Scheuerell 2002) during brewing process to promote selective enrichment of microorganisms. Several manufacturer of compost tea also provide ready use pre-packaged nutrients with similar compositions. For both ACT and NCT, fermentation nutrients have the ability to inhibit or increase growth rates for different types of organisms (Scheuerell 2004). However, nutrients should be added with extreme caution (Scheuerell 2004, Ingham 2005). Recent studies show that compost tea supplemented with molasses or other simple sugars, tends to promote growth of human pathogens such as Salmonella and E. coli, when residual levels of these organisms are present in the compost source (Ingram 2007).

Microbial supplements

It is well established that compost contains a diverse group of organisms dominated by bacteria and fungi participating in decomposition of organic matter (Droffner 1995, Brinton 2000,). Bacteria can grow and multiply in both oxygen rich *"Aerobic"* and low or no oxygen *"Anaerobic"* environments. Bacteria from genera such as *Enterobacteria*, *Serratia, Nitrobacter*, *Pseudomonads*, *Bacillus, Staphylococcus* and various *Actinomycetes* as well as fungi such as *Trichoderma spp.* have been isolated from mature composts (Droffner 1995). Subsets of these species known as "facultative anaerobes" thrive in low oxygen environment but are able to grow under aerobic conditions. It is proposed that presence of facultative anaerobes in mature compost is likely associated with disease suppressive traits. Studies have shown various fungal root rot diseases have been suppressed by incorporating compost into soil or soil-less growing media (Hoitink 1993).

Similarly, the microbial populations of NCT (Weltzien, 1991) and ACT (Ingham, 2005) have been described as being dominated by bacteria. It is stated that with ACT aerobic bacteria predominate (Ingham 2005), while with NCT the population of bacteria is mainly facultative anaerobes (Weltzien 1991, Scheueller 2004).

There is considerable interest among growers, producers and scientific community in manipulating the brewing processes to obtain optimum composition of beneficial microbes that include both aerobic and facultative anaerobic groups. To date, populations of organisms have been variable with both NCT and

ACT making any comparison of available scientific experimental results difficult (Scheuerell 2004). In addition, lack of a uniform standard method for reporting the compost tea microbiology adds to complexity of the brewing process.

Commercial suppliers advertize prepackaged microbial inoculums that can be brewed on its own, added to the compost source or to ACT following the brewing process. One of the popular microbial inoculums is "Effective Microorganisms" EM•1® developed by Dr. Teru Higa in Japan. EM•1® is a cocktail comprised of large population of facultative bacteria, yeast, enzymes, trace minerals, vitamins and organic acids. Many of the claims made for Compost tea such as plant promoting growth, and disease suppressive traits are also made for EM•1®. The groups of organisms present in the EM•1® include Lactic Acid Bacteria, Phototrophic or photosynthetic bacteria and yeast, with the diversity of species within each organism group. Material Safety Data Sheet provided by suppliers does not identify exact species or supplements included in the cocktail. There is considerable evidence in microbiology books on benefits of lactic acid bacteria and yeast in fermentation and decomposition processes. Photosynthetic bacteria can assist in converting energy into food sources for plants. However, claims supporting of roles of these beneficial microbes in plant disease suppression remain elusive. Equally unknown is effectiveness of balance of species in compost tea amended with EM•1®.

Other microbial formulations include Fungi in the genus *Trichoderma* that have been known since at least the 1920s for their ability to act as biocontrol agents (a term coined for beneficial organisms with ability to suppress pathogens) with successful results in maize (Harman 2006). *Trichoderma* species grow naturally around the plant roots and feed or parasitize on pathogenic fungi. However, if pathogenic fungi are not present in the soil, addition of *Trichoderma* can have little or no benefits as they will die-off without feeding on pathogens (Ingham 2005, Sullivan 2004).

Increasing the microbial diversity without understanding the role of each species in the context of the plant's natural environment can be risky, but is a power concept that needs to be explored further under controlled scientific experiments in the field.

Aeration

It has been suggested that aeration or oxygenation during ACT brewing process encourages growth and propagation of diverse group of good microbes extracted from the compost (Ingham, 2005), while limited or lack of oxygen during NCT brewing process may support growth of human and plant pathogens (Ingham, 2005; Scheuerell, 2004, Brinton 2004). However, there is no available scientific data that support the popular claim that only low oxygen conditions are ideal for most pathogens to grow or only aerobic condition encourages growth of beneficial microbes (Scheueller 2002).

Early studies with non-aerated compost teas (NCTs)indicated that brewing conditions that favor a brief period of low oxygen may in fact increase diversity of active microorganisms and disease suppressive properties of NCT (Scheuerell, 2004) while sterilization of NCT eliminates the microbial population and disease suppression observed in the laboratory studies (Scheueller 2002). In a more recent study, NCT and ACT brewing techniques were compared with or without aeration, and in presence or absence of nutrient additive for suppression of fungus *Phythium* damping off of cucumber seedling. The study showed that no significant correlation could be drawn between the microbial population in the compost tea brewed under continuous aeration, and disease suppression. However, addition of nutrients to ACT

during the brewing process showed the most consistent suppression of *Pythium* damping off, suggesting nutrient and not necessarily aeration support the microbial activity in ACT (Scheuerell 2006).

Aeration during compost tea production process produces fewer foul odors than the non-aerated production process. For NCT, foul odor has been reported only under conditions where nutrient additives were added during the fermentation process (Scheuerell 2006, 2002).

It remains unclear whether it's necessary to aerate during compost tea production. It should be noted that aerated compost tea or oxygenated tea in practice becomes non-aerated if not used immediately. The producers and users of ACT must take into consideration the added cost of the brewing process.

3.2 Application Process

Filtration and dilution are often necessary when the tea is applied through irrigation system or sprayers to avoid clogging the nozzle. For both NCT and ACT, filtration may remove suspended particles in the compost tea that contain beneficial microbes (Scheueller 2002). Similarly, dilution of the tea prior to foliar application may reduce the nutrients and microbial population.

For soil application, is has been recommended to use a volume sufficient to reach the root area (Brinton 1995, Scheueller 2002, Ingham 2005). Soil application is thought to protect the roots from potential colonization of root pathogens and promote healthier plants. For foliar application, compost tea is diluted 1:4 or 1:6 with water prior to application. It has been proposed that maximum coverage of leaf surface area may necessary for the beneficial microbes in the tea to outcompete colonization by plant pathogens, however, frequent and repeated applications are needed to maintain the surface coverage (Ingham 2005).

Brinton (1995) suggests addition of non-ionic surfactant such as sulfur containing formulation to compost tea prior to application can potentially decrease the frequency of application, by increasing the proportion of leaf surface area covered and prolong survival of beneficial organism in the tea against harmful UV rays. Non ionic surfactants and wetting agents, have been used extensively in pesticide/fungicide formulations for better coverage. Scheueller (2006) tested the following adjuvant in small scale compost tea trials with some success in promoting ACT-mediated suppression of *Botrytis cinerea:*

- Nu-Film-17 Foliar Spray Extender (a propriety blend derived from pine),
- Karaya Guma propriety blend of a nitrogen and polysaccharides,
- Lantron B, a surfactant manufactured by Dow Chemical Company, with following composition: 77% modified phthalic/glycerol alkyl resin and 23% butyl alcohol,
- THERMX-70 composed of 70% concentrated yucca extract which is advertized as an organic sticking agent.

There are number of other natural surfactants such as coconut oils, palm oils, castor oils, lanolin, wheat and amino acids advertized in the market for organic producers. However, research on the effectiveness of chemical or natural formulation added to compost tea remains very limited.

Table 1: Review of findings on NCT & ACT Production & Application Processes [Scheuerell & Mahafee, (2002), David Ingram (2005), Elaine Ingham, (2005), Brinton (2006)]

Compost Tea Brewing technique /	**Aerated Compost Tea**	**Non-Aerated Compost Tea**	**Issues with ACT & NCT**
Compost Source	Typically held in perforated container within the vessel –Purchased from manufacturers	Mixed with water in an open container	Source of compost is not always free of human & plant pathogens.
Compost to Water ratio	*Ratios of 1:10 to 1:50* or as recommended by Suppliers	Compost: water ratio 1:3 to 1:10	Water must be free of disinfecting agents such as chlorine or chloramines *Optimum pH i*s between 6.5 and 7.5. pH below 5.0 inhibits some beneficial microbes
Aeration	Continuous aeration-requires input of energy to deliver oxygen	Aeration is not required-only occasional stirring during the process	ACT: does not have a long shelf life. Aeration adds to cost and effort
Brewing Time	Typical brewing time is 24hrs. However, range from 18hrs to 7 days have been reported depending on the technology recommend by manufacturers	Up to two weeks but Optimum must be determined experimentally	NCT: longer brewing times prevent scheduling flexibility. ACT: shorter brewing time may result in residual nutrients that stimulate pathogen growth.
Fermentation Nutrients & Microbial inoculums	*Nutrients such as kelp, fish hydolysate, molasses, and humic* acid are often added to promote growth of beneficial organisms Addition of microbial inoculums recommended prior to application	Both Nutrient and microbial inoculums may be added but not required	Nutrients such as molasses and other simple sugars may favor growth of human pathogens such as E. coli and Salmonella if present in the compost source at residual level (David Ingram 2005/ NOP Compost tea task force 2004). Some formulation of microbial inoculums are proprietary and specify only the generic group of organisms in the mix
Filtration/Dilution	Filtered and diluted when applied through irrigation or sprayers to prevent clogging. Filtration is not required when applied directly to soil but diluted prior to application	Filtered when applied through irrigation or sprayers to prevent clogging. Filtration or dilution is not required when applied directly to soil	Filtration may remove suspended particles that contain nutrients & microbes
Addition of adjuvant (surfactants, wetting agents/ UV stabilizers) before application	Addition of adjuvant is thought to increase surface coverage for foliar application and may reduce frequency of repeated application		Chemical adjuvant have been used in pesticide formulations Research on compost tea with added surfactants is very limited

4.0 BENEFITS OF COMPOST TEA

4.1 Plant disease Suppression

Biological interactions that result in disease suppression of plant and soilborne pathogens are complex because diseases caused by pathogens occur in a dynamic environment. These interactions are thought to occur through the following mechanisms, which are not necessarily mutually exclusive.

- Antibiosis: Some beneficial organisms can produce antibiotics or other substances that are toxic to the pathogenic organisms. For example, bacteria *Pseudomonas* fluorescens strain CHAO produces hydrogen cyanide, 2,4-diacetylphloroglucinol, and pyoluteorin, which directly interfere with growth of various pathogens. Other bacteria including *Bacillus, Serrantia and fungi such as Thrichoderma* and *Gliocladium* can produce antimicrobial compounds effective against plant root pathogens (Handelsman, 1996, Haas & Defago 2005, Weltzien 1991)).
- Competition- When beneficial microorganisms are present in a growing medium they tend to outcompete pathogenic bacteria or fungi for food source (Hoitink 1993).
- Induced Resistance: Some Beneficial microbes colonizing on plant roots or foliage are documented to confer resistance to plant by turning on genes that increase plant tolerance to infection by pathogens (Haas & Defago 2005).
- Parasitism: Certain beneficial microbes can feed on specific pathogens. For example, Trichoderma species are shown in various studies to secrete enzymes that digest the cell wall of some fungal root pathogens (Handelsman, 1996).

The available literature suggests these mechanisms may be involved in compost or NCT-mediated suppression, but the mechanisms of suppression are not yet determined with ACT.

Review by Scheueller (2002) lists number of research studies conducted in laboratory, green house and field trials that suggest reducing microbial component of NCT through filtration or heat sterilization resulted in loss of NCT-mediated suppression of foliar plant diseases. However, whether suppression occurs through induced resistance, antibiosis and/or competition with plant pathogens is not clearly understood.

Fewer control studies are available on ACT or in direct comparison with NCT. In 2002, Conforti et al,, conducted a field trial at Presidio Golf Course, to assess the efficacy of ACT on turf growth and in suppressions of a common fungal disease (Michrodocium Patch/Fusarium Patch) caused by *Michrodocium Nivale.* Compost was prepared on site from vermicompost, woodchips, grass clippings, horse manure and horse bedding in equal parts and cured for minimum of 4 months, before use in preparation of the tea. Nutrient supplements such as molasses, sea kelp, cane sugar, rock dust and yeast were added to ACT during the brewing process. The resulting tea was sprayed onto greens at a rate of one gallon of compost tea per 1000 ft^2 for twelve months. Applications occurred weekly during times of high disease pressure and bi-weekly during times of moderate or low disease pressure. The study showed treated turf had substantially longer root length when compared to untreated turf. However, only limited suppression of fungal disease was observed with application of ACT. Despite limited suppression of the fugal pathogen, the treatment was considered an important improvement in golf course management.

In a more recent field trial conducted in 2007 in Ontario Canada (Hsiang 2007), ACT was prepared from a variety of commercially available composted materials such as Cattle manure, Sheep manure , Organic turkey and Mushroom compost. Field trials were conducted from August to September for suppression of visible dollar spots caused by the fungus *Sclerotinia homoeocarpa* in plots of creeping bent grass. Fungicide trials were conducted on adjacent plot and results were compared. Application of ACTs showed some disease suppression, ranging from 49 to 86% and variation was attributed to nutrients and the compost source used. The highest level of suppression (86%) was observed when mushroom compost was used to prepare ACT. 100% disease suppression was reported with the application of fungicide in adjacent plots.

ACT and NCT were directly compared in a control experiment for suppression of gray mold (*Botrytis cinerea*) on geranium (Scheueller 2006). Many of the practices for commercial compost storage, tea production, and plant management were simulated at a smaller scale. Twenty nine (29) separate compost samples including the major types of commercially available composts in Oregon and Washington were used to produce ACT and NCT extracts. The majority of compost teas (ACT or NCT preparations) did not significantly suppress gray mold of geranium, although, anecdotal suppressions were observed by both methods. With non-aerated compost tea (NCT), the most consistent disease suppression was associated with particular compost samples and increased production time, with little effect of periodic stirring or the addition of nutrients at the onset of production. Continuously aerating compost tea did not significantly increase disease suppression compared with non-aerated compost teas. Preparing aerated compost tea (ACT) with nutrient additives did not consistently increase disease suppression; when significant difference were detected, it indicated that treatment with NCT had less disease than ACT. The authors recommend a cautious approach when using additive in compost tea as there is concern for pathogen propagation.

Applying ACT with spray adjuvant significantly reduced disease when compared to ACT with no adjuvant (see section 3.2 for the list of adjuvant used in this study). The authors suggest addition of adjuvant may increase the stability microbial population in ACT.

The variability in gray mold suppression from NCT and ACT applications indicated that disease control would not be commercially acceptable. Table 2 summarizes the findings from selected studies on ACT and NCT with regard to plant disease suppression.

It should be emphasized that the mechanism (s) of compost-tea mediated suppression and the role of microbial population in NCT or ACT whether is competition, antagonism and/or parasitism remains to be delineated.

4.2 Improve Soil Structure and Plant Vitality

Compost is comprised of a large and diverse community of microbes, humic acids and other chemical nutrients such as carbon & nitrogen that support soil and healthy plant growth. Although not a fertilizer (compost feed the soil, fertilizers feed the plant), good quality compost as an organic rich soil amendment can improve soil porosity, density and improve nutrient uptake by the plant. Reviews of literature suggest compost tea may retain to varying degrees some of the same beneficial attributes of compost.

Primary interest in application of compost tea versus compost is due to the fact that composts act more slowly over a long period of time and much larger amount is required. On golf greens organic matter is undesirable, and composts are typically not recommended. Part of the reason is that they encourage earthworms.

Compost tea can be prepared in a shorter period of time and can be applied directly onto plant surface. However, effects of compost tea are short lived and frequent and repeat applications are required to replenish plant or soil surface with nutrient and/or beneficial microbes (Brinton 1995, Scheueller 2002, Ingham 2005).

Table 2. Compost Tea and Disease Suppression

Fungal Pathogens	Foliage/Turf /Soil Application	Compost Source	Compost Tea Preparation Method	Effect on Disease Suppression	Roots/Foliar Growth/Microbial Biomass	Source
Michrodocium Patches-*Microdochium nivale*	Golf Course Green	Vermicompost, woodchips, grass clippings, horse manure and horse bedding composted for minimum of 4 months	ACT supplemented with nutrients:	Partial suppression	Treated Green showed significantly longer roots than untreated turf no change observed in soil bacteria or fungal biomass	Conforti et, al., 2002.
Seedling damping-off caused by *Pythium ultimum*	Soilless container medium drenched, planted with cucumber seedling	Ground landscape cured for 3 years, vermicompost produced from mixed vegetation, cured for 3 month	ACT & NCT with or without nutrients:	13 out of 13 trials showed consistent suppression when ACT supplemented with kelp and humic acid	No correlation found between total population of microbes and disease suppression	Scheuerell, S. and W. Mahaffee, 2004.
Gray mold (*Botrytis cinerea*) –	Foliage (geranium) application	29 separate compost sources	ACT & NCT, with and without additives	Highly variable with both ACT and NCT; ACT-Enhancement of disease suppression observed by mixing adjuvant with (ACT) prior to application when compared to adjuvant alone NCT- compost class affected disease suppression	Not addressed	Scheuerell, S. and W. Mahaffee 2006.
Dollar Spot (*Sclerotinia homoeocarpa*)	Turf Green	Commercially available composted materials in Ontario, Canada (Cattle manure, Sheep manure Organic turkey, manure Organic mushroom compost)	ACT with nutrient additive	ACT-Disease suppression ranging from 49 to 86%. Fingicides-100% suppression observed with application on adjacent plots	Not addressed	T. Hsiang and L. Tian, 2007.

5.0 POTENTIAL PROBLEMS ASSOCIATED WITH COMPOST TEA

5.1 Contamination with Human Pathogens

Conflicting reports of compost tea preparations containing *E. coli,* and public concern about risk of contamination of food crops prompted the United State Department of Agriculture National Organic Standard Program (NOSP) to establish a Compost Tea Task Force in 2002. The task force reviewed available science and testimonial from growers and producers and published a final set of standards in 2004 that can be applied for the use of compost tea in organic farming. The summary of the USDA NOSP recommended standard is presented in Table 3.

In general, the task force restricts the use of manure-based compost tea or the use of nutrient additives in the compost tea for application on edible crops. While these restrictions are not imposed for application on turf and ornamental plants, the task force findings provide a starting point to evaluate systematically the compost tea production processes and consider approaches that can reduce the potential risk for introduction of pathogens in a given ecosystem.

ACT and NCT production methods were compared on growth and survival of food borne pathogens such as E. Coli and Salmonella (P3). Several commercially available nutrients, used to supplement compost tea, were tested. Compost source containing residual level of these pathogens were used to assess their growth and survival during compost tea production. Nutrient supplements used in the study included Kelp, humic acid and rock dust (fungal nutrients) or bacterial nutrient solution containing molasses, bat guano, sea bird guano, soluble kelp, Epsom salts, seabed minerals and calcium.

The findings showed that when residual levels of pathogens were present in the starting compost, the addition of nutrient supplements to both NCT and ACT supported the growth of *E. coli* and *Salmonella*. Further, concentrations of these pathogens were always greater in aerated compost tea supplemented with nutrients as opposed to non-aerated tea.

5.2 Contamination with Plant Pathogens

Reviews published by Nobel & Robert (2004 & 2009), suggests that temperature during the active phase of the composting process (although not the only determinant factor), is an important factor in elimination of most plant pathogens. For (27) out of (32) pathogenic fungi, seven (7) bacterial pathogens and nine (9) nematodes, and three (3) out of nine (9) plant viruses, a peak temperature of 64 –70°C and duration of 21 days was sufficient to reduce numbers to below, or close to the detection limits of the tests used.

Therefore, it is essential that the source compost is of good quality and meets the NOSP guidelines to avoid recurrent growth of all pathogens.

5.3 Chemical Contamination

In the United State compost, and compost extracts are not subject to any systematic rules for reporting its content, its qualities or potential risks (16,10). Further, there are no standards in place to distinguish compost-generated plant based materials or recycled waste. As such, there is limited data in support of potential chemical contaminants in Compost tea. In one published study in Switzerland (9) 13 composts and 5 extracts derived from crude organic kitchen waste and green waste were tested for chemical contaminants . The study showed presence of organic pollutants, such as Brominated Flame Retardants (BFR), Perfluorinated Alkyl Substances (PFAS), Chlorinated Paraffin (CP) and Poly Chlorinated Biphenyls (PCBs) in some of the composts and extracts derived from recycling crude wastes. The concentrations of these contaminants were at or above the levels found in background soils, which were the main recipient of compost and digestate. The authors recommended that due the persistent and bioaccumulative properties of these pollutants composts or compost extracts derived from recycling waste should be tested for these chemical contaminants.

6.0 CONCLUDING REMARKS

Review of the literature indicates the need to conduct further control field trials to better understand the brewing techniques, the application process and the benefits claimed for compost tea and compost tea additives. There are data gaps on compost quality, the role of fermentation nutrients, the need for aeration and the impact of a shorter brewing process on the quality and efficacy of the finished compost tea. Furthermore little is known about composition of microbes in the tea or microbial additives and their interaction with plant pathogens in their natural environment. Together with concerns over re-growth of pathogens in compost tea, there is a pressing need to identify the active microbes that make up the compost tea and their survival rate following field application. Finally, with new data emerging on chemical contaminants in some compost or compost extract derived for recycled waste, there is a need for establishing standards for compost quality regardless of the brewing process.

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