What is Compost Tea

The simplest definition of compost tea is a water extract of compost that is brewed, or in other words the organisms extracted from the compost, the bacteria, fungi, protozoa and nematodes, were given a chance to increase in number and activity using the soluble food resources and nutrients present in the water. An enormous diversity of bacteria, fungi, protozoa and nematodes should be present, depending on the quality of the compost.

Compost tea does NOT contain human pathogens but manure tea almost certainly does. Compost extract and leachate should not contain human pathogens either, if the compost is mature at time of use. Human pathogens are killed either by heat treatment in a thermal compost, or by passage through an earthworm digestive system in a worm compost (see Rodale s book on composting, or the SFI website for more information about the definition of good compost). Thus, compost tea does not contain human pathogens while manure tea usually does.

Compost tea must be differentiated from manure tea, leachates, and extracts:

- **Manure Tea**, a water extract of manure, can contain soluble nutrients, typically high nitrates, salts, phosphorus, and potassium, contains high numbers of bacteria unless there has been an antibiotic used in the animal feed, usually contains high numbers of protozoa, extremely low fungal biomass, can contain high numbers of nematodes, often contains root-feeding nematodes, and almost always contains human and animal pathogens.

- **Compost extract** is produced by draining water through compost. This water contains soluble nutrients but very few organisms. By cycling this water through the compost a number of times, organisms may be pulled from the compost surfaces and reach numbers adequate to protect leaf and root surfaces. This is usually not the case, however.

- **Compost leachate** is produced when water drains from over-saturated compost. This leachate typically contains only soluble materials nutrients and a few organisms. This leachate is not necessarily anaerobic, but quite often is during passage through the compost. If enough soluble sugars are present in the compost or in the leachate, then bacteria and fungi can grow and use up oxygen. This then can result in phytotoxic compounds in the leachate.

In compost tea, manure tea, compost extract and compost leachate, soluble nutrients removed from the compost can benefit plant growth, although manure teas can have too high levels of nitrate, which can burn plants. Only compost tea contains a complex set of or ganisms extracted from the compost. These organisms can improve plant growth although the correct kinds of beneficial organisms need to be matched to the type of plant (see Ingham et al. 1985 and the Soil Biology Primer, 1999).

Typically compost is the main ingredient in compost tea, but teas may also contain extracts of plant material, molasses or other sugars, proteins, carbohydrates, kelp, rock powders, rock dust, humic and fulvic acids, sources of N, etc. as additional food for microbes and nutrients for crops. Many growers have special ingredients they add to their tea. New recipes are always being tested in many different areas with the goal of achieving better plant production, better soil structure, better nutrient cycling and less disease. Please keep an eye on the Soil Foodweb web site (www.soilfoodweb.com) for updates on recipes.

Compost tea application to vineyard in Monroe, Oregon, as part of the USDA-SARE study on Compost Tea Effects on Mildew and Botrytis awarded to the Sustainable Studies Institute, Eugene, Oregon

When and Why to Use Compost Tea

Every chemical-based pesticide, fumigant, herbicide and fertilizer tested harms or outright kills some part of the beneficial life that exists in soil, even when applied at rates recommended by their manufacturers. Reviews of these effects are in the scientific literature, although less than half of the existing active ingredients used as pesticides have been tested for their effects on soil organisms. This is an oversight that should perhaps be dealt with by a comprehensive government testing program.

Compost teas, correctly made and applied, improve the life in the soil and on plant surfaces. With time and continued use, compost and compost tea of a quality designed to improve the set of organisms relative to the plant species desired, will increase the number of individuals and the species diversity of the communities of leaf, stem, flower, seed-surface and soil microorganisms, and will select against disease-causing or pest organisms. Thus use of compost tea is indicated any time the set of organisms in soil or on plant surfaces is below optimal levels for the plant life desired.

Like compost, compost tea adds a huge diversity of bacteria, fungi, protozoa, and nematodes to the substrate or place the compost or tea is applied. Typically, if the compost is well-made, only beneficial organisms are present in the compost, not diseases or pests. Making or obtaining good compost is critical, therefore. Standards for compost production and for the biological components of compost relative to the requirements of the plant are given on the SFI website (www.soilfoodweb.com). The beneficial organisms and the soluble foods to feed them must be extracted from the compost and survive in the tea in order to obtain the full benefit of a healthy compost tea.

If the whole set of beneficial organisms is extracted and survives in the tea, and if the soluble foods the beneficial organisms need to grow, then the benefits of using of compost tea for foliar or root applications include:

- pathogens cannot infect the plant tissues because infection sites on the plant surface are occupied by beneficial organisms;
- disease-causing organisms have no food and cannot grow because the exudates produced by the plant are used by the beneficial species present on the plant tissues before the disease-causing organisms arrived;
- nutrients that plants can take up through their surface tissues;
- food resources for beneficial microorganisms which are in the tea allow only beneficial, not pathogenic, organisms grow;
- microorganisms are added into soil or onto leaf surfaces, resulting in an increase in retention of nutrients, cycling of nutrients into plant-available forms, and decomposition of plant materials and toxins;
- the nutritional quality of plant produce is enhanced;
- worker exposure to potentially harmful chemicals is normally reduced;
- negative impacts of chemical-based pesticides, herbicides and fertilizers on beneficial microorganisms in the ecosystem are reduced;

- chemical input and labor costs are reduced;
- on-farm recycling of waste is enhanced;
- landfill space requirements can be reduced; and
- plant growth can be improved.

Not all of these benefits will be observed in every case of tea application, perhaps because the compost did not contain the necessary organisms, the organisms were not extracted from the compost, the beneficial organisms did not grow in the tea because the tea lacked the correct set of organisms, the beneficial organisms were killed during removal from the compost or during the growth process, such as if toxic materials were leached from poor compost, or the compost became anaerobic and killed the aerobes desired, or some other factor was not optimal.

There are two different, but not mutually exclusive, ways of applying compost tea:

1) Compost tea can be applied as a **foliar spray** to:
   a) apply beneficial organisms to plant aboveground surfaces, so disease-causing organisms cannot find infection sites or food resources (i.e., pro-biotic approach).
   b) provide nutrients as a foliar feed.

2) Compost tea can be applied as a **soil drench** to:
   a) develop the biological barrier around roots (i.e., pro-biotic approach),
   b) provide nutrients for roots to improve plant growth,
   c) improve life in the soil in general, and
   d) improve nutrient cycling, nutrient retention and disease-suppressiveness.

The biological barrier serves to prevent root disease-causing organisms from being able to detect the presence of, or find, roots (thus pesticide use can be reduced and even eliminated), serves to improve nutrient retention (thus contamination of surface and ground-water will be reduced), serves to improve nutrient cycling (thus fertilizer applications can be reduced), serves to degrade toxic materials (thus heavy metals may be made plant unavailable, plant toxins and residues will be degraded, pesticides will be decomposed, etc) and serves to build soil aggregate structure (thus water holding capacity, oxygen diffusion into soil, and root growth is enhanced, while disease problems that come with compaction will be reduced).

Foliar applications are typically no-dilution to 1:1or 1:5 dilution of the tea. Recent work is showing that dilution depends on:

1) The concentration of organisms in the tea. If the tea -produced in only within the desired range indicated on the Soil Foodweb report (see following sections on beneficial organisms in tea), then the tea should not be diluted more than 1:1. If organism numbers are greater than this, then the tea can be diluted such that these organisms are in this range.
2) If disease is visible, then tea should be sprayed directly as a drench on the affected area, without regard to a per acre amount. Drenching the affected plant tissue and immediate surroundings, where the foliar disease organism may have spread to, should be performed as rapidly as possible, typically within the next 24 hours, which is the time required to brew a tea.

3) Generally, on seedlings and small plants, such as tomato seedlings, peppers, basil, etc, five gallons of tea to the acre (50 liters/Ha), every two weeks through a disease infection period have given excellent PREVENTATIVE results. For larger plants, more tea is required. For example, a single 25-foot (8 meter) tall oak tree may require 5 gallons (20 liters) of tea to adequately cover the leaf surfaces.

The critical factor with respect to foliar applications is coverage of the leaf surface by the organisms in the tea. The two major reasons why coverage is important is that beneficial organisms must consume the leaf surface exudates, leaving no food for the disease-causing organisms so these organisms are unable to germinate or grow. Another reason is that all the infection sites on the leaf need to be occupied by beneficial organisms, so no site allowing infection is left unprotected.

Monitoring tea quality is the step most growers neglect, but without assessment following the first spray each season, it cannot be known whether coverage is adequate to protect the plant. If the leaf is covered adequately by beneficial organisms, there can be no colonization of the plant surface by disease-causing organisms. Does this always work? Given adequate coverage of the plant s surface, the answer is yes.

But this requires the plant surface to be assessed for adequate coverage in order to make certain the tea contained the required set of organisms and that these organisms cover the plant surface adequately. Recent work, within the last few months, showed that a minimum of 60 - 70% of the leave surface must be covered with bacterial biomass, and a minimum of 2 to 5% must be covered with beneficial fungal biomass in order to prevent disease from establishing on leaf surfaces WHEN DISEASE PRESSURE IS AT ITS MAXIMUM. When disease pressure was not at maximum, when conditions are not at optimal for growth of, for example, blight, mildew, anthracnose, scab, etc, then coverage of the leaf surface by bacteria alone, at 60 to 70% of the plant surface, was adequate.

Problems with tea quality

Pesticide residues in tanks, **chlorine** in water, **too cold** water either in the tea brewing or for dilution in the spray tank, application so **UV rays** destroy the organisms, temperatures **too hot** in the brewing process or too high when spraying, and **poor extraction energy** are all factors that must be recognized as resulting in poor tea, that is too few organisms in the tea.

Current work by Bruce Elliott (bruce@fish-world.com) indicates that **high bicarbonate levels** in water is easily solved, **low pH** can be dealt with without harming the organisms in the tea, and that **fungal extraction** can be improved by using the right sets of foods and materials to allow growth of the fungi in the tea.

What about duration of growth or survival of the organisms on the leaf surface? Aren t they removed by rain or wind, killed by UV, or pesticide drift? Yes, and if these materials remove or kill the protective layer of organisms, then a new application of tea is required.

Use of a biological spreader/sticker can help, but care choosing a material that does not osmotically shock or destroy the organisms is necessary. If the leaf material is still adequately covered with beneficial organisms, then the plant surface is healthy and disease cannot win in the competition for the leaf surface. How would you know if the organisms are still there? Have a leaf organism assay performed.

If disease appears after tea is used, consider then that something prevented adequate coverage of the leaf surface or killed the organisms before or after they were applied. The disease may have been mis-diagnosed, and what was called a foliar leaf disease was in fact stem rot. The soil needs to have a healthy foodweb to prevent stem rot and the tea should then be applied to the stem and soil around the plant, not to the leaves. Alternatively, if pesticide residue in the sprayer killed the organisms in the tea, then disease may occur through no fault of the conceptual approach! If a leak in the machine s pump let oil into the tea, organisms will be killed; or if pump pressure was too high or too low.

Leaf samples should be sent for analysis after the first tea spray of each season, so the quality of the tea and coverage of the leaf is assured. As long as the leaf stays adequately covered, no problems have been observed. If tea is applied and plant surface coverage has been shown to be adequate, and still disease takes over, then this is a situation that requires attention because it is unusual (i.e., has not been seen before). The author of this manual would request further interaction on this situation, because it presents a situation that needs to be understood. What allowed disease to be able to win in the competition for the leaf surface and how can we prevent this from occurring again? This situation would present a challenge to our understanding of why compost tea works, and figuring out how to overcome this challenge keeps us on the cutting edge.

Soil applications require that the soil be inoculated with the right set of organisms plus the food to feed them, in order to keep beneficial organisms functioning through the year. Typically 1 liter (0.25 gallons) of undiluted tea (if diluted, increase the amount of liquid applied to achieve the correct amount of tea) is applied per 100-mm (3 inch) tall seedling when planting into the field. The foliage and soil around the plant should be drenched by this application. A one-time application has proven adequate to prevent soil root disease if the soil contained a reasonable foodweb before tea application.

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How far down does the tea move into the soil? It depends on the soil texture, compaction and the amount of organic matter in the soil. The sandier the soil, the further down the tea, and the organisms in it, will move. The heavier the clay, the more the tea stays at the surface. Organic matter can open up structure in heavy clay, and then the tea, and the organisms, will move deeper. Organic matter usually allows the organisms added in the tea to continue growing, so added benefit is obtained from a single application of tea with greater organic matter in the soil. Compaction of course reduces the ability of water to move through soil, and increases the likelihood that inadequate oxygen is present.

If the soil does not contain an adequate foodweb set of organisms, then multiple applications may be needed. For example, in strawberry fields where methyl bromide was injected before planting, 20 liters of tea per acre (5 gallons/ac) will need to be applied at every two weeks to 1-month intervals to maintain soil health. This 5 gal of tea can be added to any amount of non-chlorinated water, as long as the full 5 gal of tea is applied to the 1 acre of area.

An alternative is to apply good compost around the root systems of the plants, so soil drenches of tea may not be necessary. **As always, if disease is observed, then a tea application is immediately indicated.**

In the greenhouse or nursery or a field where disease has been a problem, the soil should be drenched before planting. In pots, a drench means water should just barely begin to drip from the bottom of the pots. Be careful that the tea does not just run along the inner surface of the pot and out the bottom of the container. In the field, soil should be wetted to the depth of the plant s root system. Once plants are planted, apply tea to the foliage as well as using a soil drench. In situations where disease has been serious, saturate the soil surface, and maintain stem and leaf coverage by tea organisms every week to two weeks to keep the soil and plant healthy. If problems are encountered, feedback is requested, so unusual situations can be explored and solutions found.

Factors Affecting Compost Tea Quality

Compost tea can be inconsistent from batch to batch, but this variability is actually relatively easy to control. When making tea, test the tea periodically to make sure the set of organisms in the tea is maintained and no unexpected problems occur to harm extraction and growth of the organisms.

Compost Source and Quality. All of the soluble compounds in compost are potentially extractable into the tea. It is essential, therefore, that only beneficial food sources be present in the material being extracted. Only by composting correctly can this be assured. Whether using thermal, or static compost, temperature must have reached AT LEAST 135° F (57° C) continuously for 3 entire days throughout the entire pile (the surface of the pile is not at 135° F (57° C), so the outside material must be turned to inside and temperature maintained). The material cannot have been anaerobic for any length of time or phytotoxic compounds may be present (see the outstanding work by Brinton, 1995). If worm-compost (vermicompost) is used, the material does not have to reach temperature, but must be adequately processed by the worms. Passage through the earthworm digestive system kills human pathogens and most plant pathogens, although more work needs to be performed to document this in a fully scientific manner. Adequate time in the worm bin must be allowed for full processing of all materials by the worms to occur.

All of the species of organisms that can be detected in the compost being extracted will be extracted into the tea. This does not mean all individuals of all species of organisms will be extracted however. Many individuals will be left in the compost, so the compost can be re-added to the compost pile. If pathogenic or pest microorganisms are present in the extracted material, then they too will be extracted into the tea. Therefore, **GOOD COMPOST, which does not contain disease-organisms,** is essential.

If compost is properly made, disease-causing microorganisms will be killed, out-competed, inhibited or consumed by beneficial organisms in the compost, or in the tea. A huge range of beneficial food resources is made during the composting process (see Cornell s Handbook on On-Farm Composting, Rodale s books on composting, and the Soil Foodweb Web Site for more information on making good compost).

If you buy compost, how do you know the compost is good? Data are REQUIRED. Ask your compost supplier to show you the documents indicating that temperature reached adequate levels for long enough during the composting process. Ask them to show you the data on oxygen concentration (or the reverse measurement, carbon dioxide concentration) during the composting operation. Because the heat during composting is generated by bacterial and fungal growth, that increase in temperature also reveals that the bacteria and fungi are using up oxygen in the pile, and the compost may become anaerobic when the organisms grow rapidly, i.e., during peak temperature times.

Temperature must exceed 135° F (57° C) for at least three days, which means the pile temperature should be maintained above that for 8 to 15 days, with turning, to make sure everything in the pile reached temperature for long enough. The temperature should, however, not exceed 155° to 160° F (68° to 71° C) and the oxygen level should not drop below 12 to 15%. When temperature reaches these high ranges, oxygen is being consumed rapidly, and anaerobic conditions, with production of phytotoxic materials, is quite likely. If compost gets too hot, does not heat enough, or becomes anaerobic, the set of organisms in the compost is not desirable. If you use poor compost, the tea will not contain the desired set of organisms.

The best test of compost that you can do yourself is to smell the compost. It should smell sweet, like soil. If it has gone anaerobic for a significant period of time during composting, it will smell sour, like vinegar, or sour milk, or vomit, rotten eggs (hydrogen sulfide) or urine (ammonia). Not only will the material have lost nitrogen and sulfur (and why would you pay good money for something now lacking fertility?), but it also contains phytotoxic materials that can kill your plant if they encounter any plant surface (again, see Brinton s work, Woods End Lab, on volatile organic acids).

In order to maximize the populations of beneficial organisms, it is important that an adequate range of food resources be extracted from compost into the tea. This can only occur if organism numbers are adequate in the compost. It is the organisms that make humic and fulvic acids. Minerals will be extracted from the compost as well, making it critical that the salt level not be too high, and that no toxic chemicals, or at least no high concentrations of toxins, be present.

Maintaining Compost Activity.

If you buy a large amount of compost to use to make tea during the rest of the year, be aware that the organisms in the compost go to sleep, become dormant, and don t extract from the compost easily the older compost gets. You have to maintain compost activity, by adding back compost tea to the compost. That keeps the organisms alive and happy. Even then, we have seen a compost get so mature that you can t wake them up to grow at all in a 24 hour brewing cycle.

Compost for compost tea needs to be SLIGHTLY IMMATURE! That means, a little bit of temperature is a good thing — about 5 - 10° above ambient is the desired range.

Mesh size of the tea bag or final filtration material. The size of the holes in the compost container, whether bag or solid, or in any filters through which the tea must pass, determines the kind of particulate material and organisms that will be present in the tea. Mesh is a measurement of the number of holes in an inch surface area, the smaller the mesh number, the larger the size of the holes. For example, an 80-mesh screen has holes with diameters of 170 micrometers (a micrometer is a millionth of a meter). A 20-mesh screen has holes with diameters of 800 micrometers.

The finer the size of the openings, the more likely only soluble components will be extracted. If the openings are too large, particulate matter in the tea may clog sprayers and irrigation systems.

A variety of materials can be used for filters, as long as they are inert to microbial decomposition. For example, polycarbonates, plastic, nylon, silk and fine-weave cotton work well, but window screening, wire mesh, and burlap may also be used. Fresh burlap should be used with caution, though, as it is soaked in preservative materials which can be extracted into the tea and kill the organisms.

Consider the size of the organisms desired in the tea. The largest beneficial nematodes are around 150 to 200 micrometers (10^{-6} meters) in length, but only 30 to 50 micrometers in diameter. Thus, a mesh that allows organisms of this size to pass, but restricts passage of larger materials, is desirable. The openings should not be smaller than this size since then a number of the beneficial organisms would not be present in the final product.

Brewing time. The longer the brewing time, i.e., the time the compost remains suspended in the water or tea solution, the greater the amount of soluble material extracted from the compost and the greater the number of organisms extracted. More soluble material in the tea means more food resources to grow beneficial bacteria and fungi, and more nutrients that will potentially be made available for plants.

The easiest way to know how long your machine takes to make good tea, with adequate organism numbers in it, is to measure the number in the tea over time. There are machines with 12 hour brewing times, and some with 24 hour brewing times.

The organisms growing in the tea consume these nutrients, immobilizing them in their biomass and keeping the nutrients from washing through soil or off the leaf surfaces. If the tea is well mixed and well aerated (see Compost Tea Production Methods), microorganism growth and extraction of soluble nutrients will be maximized. Brewing beyond that time means the organisms will run out of food and may begin to go to sleep or die.

If oxygen supply is not adequate, bacteria and fungi growing in the tea can use oxygen faster than oxygen diffuses into the tea, and then anaerobic organisms grow in the tea with the production of potentially phytotoxic materials in the tea. Any corner of less than 120 degrees tends to be a place where bio-films form rapidly, a well-known phenomenon in the world of biofouling. Despite any amount of mixing in the container, the dead-air ef fect of a corner results in no replenishment of well-oxygenated water, so that oxygen is rapidly depleted as microbes grow. Thus corners can result in the production of rank-smelling materials, and have quite negative impacts on plant growth if these anaerobic decomposition products are not used by aerobic organism growth before the tea is placed on or around the plant.

The shorter the brew time, the less likely it is that anaerobic bio-films can develop. Thus there is a balance between extraction of nutrients and growth of organisms, giving an optimal time for tea production, depending on the exact conditions of brewing.

The longer the brewing time, the more likely weather will change and application will have to be put off. With longer brewing times, the organisms in the tea will use up all their food and go to sleep, or if brewing times are very long, some of the organisms colonize the surfaces of the containers and begin to develop anaerobic layers on the container walls. Thus, there needs to be a balance between the time organisms immobilize nutrients extracted from the compost and the time they will begin to colonize the container walls and produce anaerobic layers. This becomes a Goldilocks principle — enough time but not too much time (the porridge needs to be not too cold and not too hot, but just right).

Each tea brewing machine or set-up has an optimal time for extraction unique to the exact extraction efficiency, growth conditions, aeration, and mixing characteristics of the machine. For example, the Microb-Brewer and the Earth Tea Brewer can produce the optimal number of organisms within 20 to 24 hours when run at room temperatures (colder temperatures require longer brew times). The BioBlender takes 48 hours to produce the same numbers of organisms. The bucket method of brewing (see Ingham, 2000) requires 3 days, and some trough methods of production, and most anaerobic brews, require 2 to 3 weeks. In anaerobic methods, the material often goes through an anaerobic period and returns to aerobic following the peak in bacterial growth.

It is possible, however, to have such low numbers of organisms in a tea that bio-films never develop. Regardless of whether compost lacks organisms (of course, it is not really compost then), or extraction efficiency was minimal, if the tea does not contain many organisms, the tea will never become anaerobic, no matter how long the brewing time. Of course, then the tea is not capable of adequately covering leaf surfaces or providing an Inoculum of organisms to protect roots.

The Water Source. Water high in salts, heavy metals, nitrate, chlorine, sulfur, tannic acid, carbonates, or contaminated with pathogens (human, animal or plant disease-causing microorganisms) should not be used. Where any of these are present, removal of these contaminants becomes a priority before using the water. Both chlorine and sulfur can be removed by aeration. Carbonates can be removed by precipitating them with additives, and then de-gassing those additives.

Contact your water treatment department or send a water sample to a testing lab for analysis. Here are some very rough indicators of problems. Drink a glass of bottled water (make sure it is less than 1 ppm (μg/ml) nitrate. Drink a glass of your own water. Bitter? High nitrates. Rotten egg taste? High sulfur. Chlorine smell? Too much chlorine. Slippery feel to the water? High in carbonates. Use some phosphoric acid to balance the pH or chlorine to precipitate the carbonates. Earthy taste? Algal or actinomycete growth in the treatment plant. Find a better source of water.

Added Materials. Many ingredients can be added to compost tea to enhance the growth of specific microorganisms and provide micronutrients for plants. This manual gives a basis for choosing some of these materials (see The Recipes later in this manual), but a great deal more work is needed to understand why some additives work in certain conditions but not in others.

Extraction/Mixing. This is a Goldilocks Principle : Mixing needs to be just right , not too much and not too little. **Too rapid** mixing will physically destroy beneficial microorganisms in the tea. Think about yourself impacting the wall of the container going 320 km (200 miles) an hour. If the speed of the impact would kill you, it will kill the organisms in the tea. **Too slow** mixing means a lack of organisms pulled from the compost, allows bio-film development to be rapid, and the surface of everything will develop an anaerobic slime with resulting phytotoxic materials present in the liquid.

There are two things to understand about mixing.

1. Enough energy has to be imparted to the compost to physically remove the bacteria and fungi from the surface of the compost. Bacteria can glue themselves onto the surface of any particle in compost, and it takes significant energy to remove bacteria from these surfaces. Fungi wrap around particles and the hyphae have to be broken enough to let the strands be pulled out of the compost, but not broken so much that they are shredded into tiny pieces. Thus, most extraction methods that involve blades, whirring mixing bars, or blender action can break the hyphae, or the bacterial cells, up too much and result in poor fungal and/or bacterial biomass in the tea.

2. Uniformity of the end product, the tea, is necessary. Good mixing — enough but not too much - produces both effects. Most of the commercially available machines were developed around the principles of enough aeration and enough mixing to get organisms into the tea, but not shred them to death.

Recent work has shown that if you SEE the brown color coming out of the compost, then you are likely to be getting the fungal extraction you want. You still want further fungal growth in the tea, and you need to look for fungal food resources and fungal surfaces that will allow fungi to grow in tea. So, BEFORE placing any dark-colored materials in to the tea water at the beginning of the cycle, put the compost into the tea maker, in whatever container you have, and make certain the compost tea-maker is mixing the water well enough to pull the humic acids out of the compost. No brown color out of the compost in the holder should instantly indicate that adequate extraction of fungi is not possible. Additional mixing of the compost in the container will be necessary.

Aeration. Oxygen is required by all aerobic organisms. A large problem in making highly beneficial teas is when microbial growth rapidly uses up a significant portion of the oxygen such that anaerobic conditions ensue, and materials that are toxic to plant growth are produced in the tea. Properly controlling oxygen input into the water is critical. It is a wise idea to buy an oxygen probe in order to make certain the tea remains in the aerobic range (above 6 ppm or 70 to 80% dissolved oxygen — versus carbon dioxide - in solution).

Tea applied once to area on right, normal fertilizer applications to remaining lawn; Ariadne Gardens, Portland

Oxygen has to diffuse into water at the interface between air and water. By bubbling air into water that interface is increased, resulting in more diffusion of oxygen into water. The smaller the bubble size, the greater the exchange surface, and the more efficient the transfer of oxygen into the water. Bubblers that decrease the size of individual bubbles improve the oxygen content of water more rapidly than aerators with larger size openings to produce bubbles. Of course, if the bubble size is extremely small, then airflow may be restricted because it is harder to push air through a small opening. Aquarium bubblers typically produce rather large size bubbles and are not very efficient oxygenators of water, but they are very inexpensive and can run all the time. Depth of the water is important too, since in order to produce a bubble, the air pressure must be greater than water pressure, and water pressure increases with increasing depth. Thus an air pump adequate for a 5-gallon machine may not be adequate for a 500-gallon machine, depending on the water depth.

If bacteria and fungi are not growing, tea solutions will remain well oxygenated. Bacteria consume the majority of the oxygen during aerobic metabolism. If the oxygen is replenished at a rate greater than what is consumed by the bacteria, the tea will remain aerobic. Conversely, when oxygen is consumed at a rate greater than the rate at which it is replenished, the tea will become anaerobic.

When dealing with tea, and the need for a short brew cycle, the growth of bacteria and fungi can be so rapid that air can be drawn below aerobic levels extremely rapidly, within an hour or less of adding molasses, humic acids or other food resources. Therefore, air needs to be provided at a relatively high rate to offset the use of oxygen by the aerobic, beneficial organisms.

Teas can become anaerobic if molasses or sugar is added to the solution. The offensive odor produced (rotten egg smell, vinegar or sour smell, sour milk or vomit smells) is an indication of anaerobic conditions. However, if the tea is allowed to continue— fermenting, microorganism growth slows as food resources are used up. Oxygen will begin to diffuse into the tea more rapidly than it is consumed by bacterial and fungal growth, and aerobic organisms will begin to grow using the organic acids produced during anaerobic metabolism. The tea will become aerobic again.

Strict aerobes require oxygen concentrations around normal atmospheric levels (18 to 22%, or 8 ppm, or 8 μg per liter) in order to perform the functions of life. Examples of some of these genera of bacteria are Pseudomonas, Bacillus, and Aerobactor. As oxygen concentration is reduced, dropping below 5 ppm, strictly aerobic organisms will become dormant, and eventually die. Lack of oxygen allows the growth of facultative anaerobes (which switch from aerobic to anaerobic metabolism when oxygen levels fall below 15 to 16% O_2 or 5 to 6 ppm oxygen). Examples of bacteria that are facultative anaerobes are E. coli, Klebsiella, and Acinetobactor). True anaerobic bacteria (cannot tolerate presence of O_2 above 7 to 8%, or 4 to 5 ppm oxygen) and strict anaerobes require low oxygen concentrations (less than 2% oxygen) to grow.

Anaerobic organisms are not detrimental in themselves, but their metabolic products can be extremely detrimental to plants as well as many beneficial microorganisms. Anaerobic metabolites produced are volatile organic acids (valeric acid, butyric acid, phenols, see Brinton, 1997) that are very detrimental to the growth of plants and beneficial bacteria, fungi, protozoa and nematodes. Anaerobic products may kill some disease-causing microorganisms, but usually the death of a few disease-causing microorganisms is not positive enough to offset the reduction in plant growth.

A word should be said about anaerobic compost tea fermenters. The term fermenter has been used in many different ways and today should probably be interpreted to mean only growth vessel . In the past, the term fermentation was linked to alcohol production, a process that requires anaerobic conditions, and the containers, called fermenters, were the growth vessels for yeast. However, today, many people use the term for any vessel that grows microbes, aerobic, anaerobic or in-between.

When aeration is too great, the tea can become over-charged with oxygen, which can be detrimental to beneficial microorganisms. However, there is no compost tea maker on the market that over-charges tea. Only if someone decided to add hydrogen peroxide, or ozone to the water would it be likely that the water could have too great an amount of oxygen.

Aerobes, facultative anaerobes and strict anaerobes are everywhere. They live in soil, on plant surfaces, on the surfaces of stones, on and in pavement and clothing. Facultative anaerobes include some species that are highly beneficial to plants as well as some disease-causing species. These microorganisms are needed so that the cycling processes within nature can occur. Thus, sterilization of tea is not the answer. Many highly beneficial microorganisms would be lost if the tea were sterile. The goal is to keep the tea fully oxygenated and maintain aerobic conditions, so that the benefits from a widely diverse set of microorganisms can be realized.

Microbes in tea. A wide diversity of bacteria, fungi, protozoa and nematodes need to be present in the compost and be extracted into the tea (see following sections on the organisms in tea). When the diversity of beneficial microorganisms is high, the greater the likelihood that disease-causing organisms will be out-competed on leaves, stems, roots or in the soil. Nutrient retention will be higher, because all the food resources will be used and the nutrients retained and not leached from the leaf, stem, root or soil. Plant-available nutrients will be cycled at a more beneficial-to-the-plant rate, and soil aggregation will improve, along with water-holding capacity, breakdown of toxic materials and decomposition rates. When the diversity of microorganisms in the compost is low, the health of plant surfaces will be limited, and one particular set of metabolic products can accumulate to the detriment of plants and other microorganisms. Thus good compost is critical to the production of good tea (see Wagner, 2000, Rodale books on composting, the Soil Foodweb website, www.soilfoodweb.com for information about the set of organisms in good compost and how to tell if they are present).

The Ratio of Compost to Water. The dilution of soluble materials and microorganisms extracted into the tea is important. Too little compost will result in too dilute a tea with too few nutrients or organisms. Too much compost means not everything is extracted that could be extracted. If the spent compost is placed back into an active compost pile, then wastage isn t a worry. But it may be possible to overload some tea makers with too much compost, such that water cannot flow through the compost and extraction efficiency will be low. Because the optimal ratio of compost to water tends to be variable, experiment with the amount of compost put in your compost tea brewing machine to find the best ratio. If your machine calls for 7 pounds or kilos of compost, try 6 or maybe 8 pounds or kilos and see if the amount makes a difference.

Recent testing has shown that if the extraction of the machine is optimal, the compost needed is less than currently being recommended by many tea-machine makers. For example, in a 500 gallon Earth Tea Brewer, for example, only 15 pounds of compost made a tea with organism numbers above the desired range based on Soil Foodweb tests for adequate disease suppression. Not only was extraction optimal, but the fungal-tea starter materials resulted in the growth of beneficial fungi in the tea during the 24 hour brewing time.

Temperature. Temperature, humidity, evaporation and other abiotic conditions influence the growth rate of microorganisms. For example, high temperatures volatilize nutrients. Evaporation concentrates salts, while low temperatures slow microorganism growth. Obviously, these conditions can have a significant influence on the quality of the tea. Again, experiment a bit to find the optimal temperatures for your particular situation.

Place the tea making equipment inside a greenhouse or shed. In hot weather, cover or shade tea-making units prevent evaporation and concentration of salt.

In machines where the tea goes through a pump, the growth of microorganisms elevates the water temperature, but as long as the tea is well mixed, temperatures will not exceed 100° - 110° F (38° - 43° C). If temperature in the machine exceeds 100° F (38° C), something is wrong with the pump, or too much biofilm has developed in the pipes or tubes, suggesting that the machine should be cleaned to remove restriction of the passageways in the machine.

Machines that are mixed with air and the tea does not go through the pump are cooled by the temperature of the ambient air and rarely have an increased temperature. In these machines, it is wise to use a tank heater to raise temperature and increase microbial reproduction.

Foam. The presence of foam on the surface of tea is considered a positive sign, but just means there are free proteins, amino acids or carbohydrates present. This can occur as the result of adding fish hydrolysate, certain organic acids or carbohydrates. If worm compost was used, excessive foam suggests a few earthworms were in the compost and their dead bodies are providing this source of protein/carbohydrate. Excess protein or amino acids should not occur if bacteria are growing well, although dead worms may continue to release proteinaceous materials throughout the brewing cycle. Foam can be suppressed by using organic surfactants, such as yucca or vegetable oil (not olive or canola oil!). Don t use commercial de-foamers — every single one we have tested kills the organisms in the tea.

Beneficial Organisms

Compost should contain a maximum diversity of many types of bacteria, fungi, protozoa, and nematodes. If the conditions are right, the microbes in the compost will be extracted into the tea solution. Higher quality compost will have a more diverse microbial population, resulting in greater diversity in the compost tea.

Bacteria. Good compost teas have on the order of a billion bacteria per ml (10^8 to 10^9 bacteria per ml), most of which are beneficial to plant growth. Highly aerobic teas, such as those produced by the Microb-Brewer, the Earth Tea Brewer and the Bio-Blender (see section on commercially available units), can contain even greater numbers of microorganisms, (on the order of 10^{10} to 10^{11} bacteria per ml).

Since coverage of leaf surfaces by the tea organisms, or the density added to the soil, is what is important, these numbers mean that 100 times more tea from a bucket method might be needed to achieve the same results as from one of the commercial units. Alternatively, consider that tea from the commercial units could be diluted by 10 to 100, if maximum extraction and growth were achieved.

Bacteria basically glue themselves to surfaces, and thus it is necessary to apply enough energy to the compost material to physically pull these organisms from the compost particles in order to get them suspended into the tea. Some of the initial testing with the Microb-Brewer was determination of the strength of the vortex in the liquid that would remove organisms from the compost, but not destroy those organisms by applying so much force that the organisms were killed by impact on the surfaces of the brewer. Similarly, this testing needs to be performed with other machines, to make certain the physical blending performed does not macerate or disintegrate some of the organisms. Recent testing shows the Bio-Blender and Earth Tea Brewer do not suffer from this problem.

How to Measure Bacterial and Fungal Numbers. The best way to assess both active and total bacterial and fungal biomass in any material is through the use of **direct methods.** The organisms are viewed and counted and there is no question that what is being counted is the organism of interest. There is no requirement to know what food resource is needed to grow the bacteria or fungi, what temperature the organisms grow at, what humidity is required by the different species, etc. It is impossible for a single set of incubation conditions to meet the growth requirements for all the different species of bacteria or fungi. For example, a plate count assessment cannot enumerate both heat-loving and cold-loving bacteria species, wet-loving and dry-loving bacterial species, species requiring high N and those requiring low N. Whereas direct methods can assess total or active biomass of bacteria or fungi in any kind of material.

No incubation step is required using direct methods. There is no guess required with respect to dilution. Samples are finished within several hours of arrival in the lab so if a different dilution is needed, the original sample can be used. The actual sizes of the bacteria and fungi in the sample are measured, so no guesswork about bacterial and fungal biomass occurs with this method.

Plate methods are best for identifying certain microbial species using biochemical reactions and selective growth media. When technological methods for performing direct count methods were not particularly reliable, perhaps 20 to 30 years ago, plate counts were used to estimate total or active bacterial or fungal numbers in soil. However, no one particular type of medium can grow all the different bacteria or fungi that occur in any environmental sample, including compost or compost tea. Consider that the microorganisms in your soil, or tea, or compost, grow at many, many different temperatures, use many different foods, like a whole range of moistures and humidities, none of which are mimicked by conditions in an incubator.

In plate counts, ten-fold dilutions are typically prepared and the quantifier has to guess which dilutions to plate on the medium chosen. Plates are then incubated at one temperature, one moisture, one humidity, one set of limited carbon, nitrogen, P, K, Fe, Ca, etc. concentration. The plate that has a countable number of colonies, between 30 and 300 per plate, is counted at 1 and 2 weeks, but how many of the total bacteria present were missed? How can you possibly know which ones were active in the conditions of your soil? Microbiology texts discuss problems with plate count methods (i.e., Sylvia et al., 1999). Plate counts always underestimate the number of actual bacteria present, but what is not known is by how much numbers are under-estimated - 2-fold, 10-fold, 1000-fold, or more?

Why Are Bacteria Needed in Tea? In foliar teas, bacteria occupy most of the leaf or root surface and thus are most effective at consuming the food resources that the disease-causing organisms would otherwise consume. Bacteria occupy most of the infection sites, which would otherwise be occupied by the disease-causing organisms. In soil, bacteria have additional functions beyond consuming foods and occupying infection sites, they also retain nutrients (N, P, S, Ca, Fe, etc) in their biomass (given the C:N ratio of bacteria, they cannot mineralize N, they have to be immobilizing N in their biomass — the exception is nitrifying or ammonifying bacteria which use N as electron acceptors or donators, but these are unusual and very special processes which occur in particular conditions in soil). Bacteria also decompose plant-toxic materials and plant residues (especially the simple, easy to use substrates), and build soil aggregate structure. The smallest building-blocks of soil structure are built by beneficial bacteria. Without these bacteria, the bricks to make the soil house will not occur and further development of soil structure will not happen, and water-holding capacity can never be improved and soil will remain compacted. Bacteria build the bricks that allow passageways for oxygen diffusion into and carbon dioxide out of the soil.

Thus, it is critical to have bacteria in high enough numbers, and with as great a diversity of species as possible, so that some portion of these bacteria can function within existing environmental conditions and suppress various cultivars or races of disease-causing organisms. Most of the bacteria added in the tea will not be the right ones at the moment you add the tea, so they go to sleep in the soil, and wait for the right conditions that will allow them to wake up, suppress their competitors, retain nutrients, decompose residues, and build soil aggregate structure. But of the tens of thousands of species of bacteria added in tea, several hundred will match the growth conditions present at this moment, and suppress disease, retain nutrients, decompose resides and build soil aggregates. What are the names of these bacteria? We don t know. We can t grow them on ANY culture medium; plate count methods cannot be used to assess these organisms.

Do we have to know the names of each of these bacterial species in order to get them to work for us? No. Until science develops ways to inexpensively identify them, just get the critters in tea working without worrying about their names. Let plants select the active organisms; the plant feeds those organisms that prevent diseases around its roots, leaves, stems, etc. Stop killing beneficial bacteria and fungi with toxic chemicals and let the organisms in soil do the work nature designed them to do.

Fungi. There should be 2 - 10 meters of active fungal biomass per ml, and 5 - 20 μg total fungal biomass per ml in good compost tea. Decent compost, which should contain 150 to 200 μg of total fungal biomass per gram, contains both simple extractable carbon sources (sugars, proteins, amino acids, simple organic acids) as well as more complex fungal foods (complex amino-sugars, complex proteins, hormones, siderophores, complex carbohydrates, phenols, tannins, and humic acids). Simple carbon sources are easier to extract than more complex molecules, but fungal require the more complex molecules as their food resource.

Energy must be provided during tea-brewing to extract complex molecules. Complex molecules are needed so fungi have something to grow on in the tea. Fungi also have to be extracted from the compost, which means the aggregate structures that fungi form must be broken, and the fungal strands teased free into the tea solution. This is tricky, to provide enough energy to disintegrate aggregates and to break fungal strands, but not destroy them.

Why, specifically, do you need fungi in tea? Just as with bacteria, there are lots of reasons, but reasons very similar to bacterial reasons. Fungi and bacteria are, not always but in general, in competition with each other for food, space, oxygen, water, etc. Plants generally require either bacterial-dominated, or fungal-dominated soils because the microbes control nutrient cycling, the FORM of the nutrients (yes, the FORM of N is important to a plant, most trees do NOT do well with nitrate. They ll use it, but nitrate/nitrite tends to select for disease conditions along the roots. Thus ammonium, which is controlled by fungal presence, is a much better choice for a tree).

In foliar teas, fungi account for only 20% of the coverage of leaf surfaces, but they may be very important to complete coverage, and competition with any disease-causing organism. One reason why simply spraying a single bacterial species to control blossom rot doesn t work is because the environmental conditions favor another bio-control agent, or fungi may be the most important for preventing the growth disease-causing organisms. Beneficial fungi may be needed to consume the exudates that plant leaf surfaces, stems, blossoms, etc., produce, so there is no food to allow the disease-causing organisms to germinate and/or grow on the leaf surface. Infection sites on the leaves may need to be occupied by beneficial fungi so that disease-causing organisms cannot infect the plant.

In soil, fungi have additional functions beyond competing for nutrients and occupying infection sites and thus suppressing pathogen growth. These additional functions include:

1. retention of nutrients (N, P, S, Ca, Fe, etc) in fungal biomass (the C:N ratio of fungi means that fungi cannot possibly be mineralizing N, they have to be <u>immobilizing</u> N in their biomass - fungi are the major holders of Ca, at least in soils we have tested),
2. decomposition of plant-toxic materials and plant residues (especially more recalcitrant, less easy to use substrates), and

3. building soil aggregate structure. The visible aggregates that are seen in soil are built by fungi by binding together the bricks made by bacteria, or ganic matter, root hairs, fecal pellets provided by soil arthropods, etc. Without fungi, visible aggregate formation would not occur as often, and further development of soil structure would not occur. Water-holding capacity would be more difficult to improve, and soil would remain compacted, because fungi build the hallways and passageways between aggregates that allow oxygen to diffuse into the soil, and carbon dioxide to diffuse out of the soil.

Thus, it is critical to have fungi, in high enough biomass and with as great diversity of beneficial species for the plant as possible to be present, so that at least some species of beneficial fungi will be functioning within the existing environmental conditions. It is the fungal biomass that is most rapidly destroyed by continuous plowing. Fungal biomass is typically lacking in any field that has been plowed more than 10 to 15 times. Thus, they are critical components to return to the soil.

Most of the fungi added by applying tea will not be functional at the moment the tea is added. They may be dormant, and if active, conditions in the soil are quite different from those in the tea. They may go to sleep quite rapidly after addition and wait for the right conditions that will allow them to wake up, suppress their competitors, retain nutrients, decompose residues, and build soil aggregate structure. But of the thousands of species of fungi added to the soil in tea, perhaps for a hundred, conditions in the soil will match the ones that are best for them to grow and perform their functions. Which set of fungi will this be? What are their names? We don t know. We can t grow them on ANY culture medium; there is no plate count method that can enumerate them. We can detect them using molecular approaches, but we then cannot match their function to their DNA sequence.

Do we have to know the names of each of these fungal species in order to get them to work for us? No, of course not. So until methods develop to identify them, let s just get these fungi back into the soil, let the exudates plants produce select for those which best serve the plant. We should not kill beneficial fungi with toxic chemicals or too high levels of inorganic fertilizers.

Protozoa. Three factors are important for protozoan extraction, to reach the 20,000 individuals required in the tea per mL:

1. Breakage of aggregates so protozoa can be extracted from these previously protected surfaces.
2. Energy needs to be supplied to pull the protozoa off surfaces, but not kill them.
3. Time should be minimized during which protozoa are subject to changes in pressure that results in cytolysis, or breakage, of individuals. Thus, brewing time should be minimized.

If the Goldilocks Principle is adhered to, the brewing process results in extraction of a lar ge proportion, but not all, of the protozoa from compost.

Protozoa eat bacteria, releasing nutrients that stimulate the growth of bacteria, fungi, and plants, if plants are present (which is what happens on leaf or root surfaces or in soil). So, when scientists say that bacteria mineralize N in soil , what is REALL Y happening is that protozoa mineralize N as they consume bacteria. Many scientists just haven t understood the actual mechanism.

With time, protozoa will increase in number in the tea, but when brewing times are short, there is no time for reproduction to occur. For example, a 20-hour brew time is not enough time for an increase in numbers, and only the protozoa extracted directly from the compost will be present in the tea. For short-term tea makers, this means use of a good compost is critical in order to extract the protozoa from the compost, since growth will not be possible during the extraction time. Teas that are brewed longer can have protozoa grow in the tea. For example, in a three days tea brew cycle, protozoa could multiply, giving a 3 to 6 times increase in numbers.

Flagellates and amoebae do not tolerate reduced oxygen conditions at all well. If the tea becomes anaerobic at any time, these groups of protozoa will be killed. Thus flagellates and amoebae are good indicators of aerobic conditions — if their numbers are low, anaerobic conditions or extreme mixing pressures are indicated.

Ciliates, on the other hand, tolerate anaerobic conditions, and indeed, apparently prefer to feed on anaerobic bacteria. High ciliate numbers in tea, or soil, or compost are indicative that anaerobic conditions occurred sometime during the production cycle, although conditions may not be anaerobic at the time of sampling. Anaerobic conditions could have occurred in the PAST, and no longer be a problem.

Immature compost most likely will not have a decent set of protozoa, and therefore cannot be extracted into the tea. Compost needs to cool to at least 125° F (50° C) before most protozoa will start to reproduce normally. Thus, a pile should cool at least 1 week, without turning, after falling below 125° F (50° C) to allow the protozoa to grow and reach minimum numbers (10,000 per gram dry weight of compost) throughout the compost pile.

Nematodes. Like protozoa, nearly all the nematodes in the compost will be extracted in most tea making machines because enough energy is applied to the compost to pull these organisms out of the compost. Dripping water through the compost is not adequate for extraction, however. Good compost normally contains fifty to several hundred beneficial nematodes per gram, all of which will be extracted into the tea. Thus, if 20 pounds (9 kg) of compost are used to make 50 gallons (200 liters) of tea, there should be about 11 nematodes per ml of tea, or 2.3 X 106 nematodes in the whole tea batch. All these nematodes should be beneficial; only poor compost would contain root-feeding nematodes.

Nematodes play a number of different roles in soil, and it is important to recognize that while one group of nematodes is detrimental to plant growth, most nematodes in soil are beneficial for plant growth. There are four major functional groups of nematodes in soil:

- Plant-feeders are the bad guys , and consume root material, reducing plant growth and yield,
- Bacterial-feeders consume bacteria, releasing N, P, S, etc which are then available for plant uptake,
- Fungal-feeders consume fungi, releasing N, P, S, etc which are available for plant uptake, and
- Predatory nematodes that consume other nematodes and keep the population numbers of the bad guys, and the good guys, under control. Too many bacterial-feeders could reduce

bacterial populations below the level needed to suppress disease, retain nutrients, decompose residues, or build soil aggregates. Thus predators are important controls on the foodweb system.

Compost that has been properly made will not contain root-feeding nematodes, but care is needed to choose compost that is nearly mature in order to have a good set of beneficial nematodes in the compost. Beneficial nematodes do not start to grow in a compost pile until after temperature drops back to less than 115° F (45° C). Both predatory and most fungal-feeding nematodes are killed if the pile is turned too often. Thus, the pile has to mature, unturned, at least two to three weeks AFTER temperature has dropped below 115° F (45° C).

Mycorrhizal fungi do not grow in tea solutions, although spores and hyphae will be extracted into the solution from the compost. The heating process during composting often kills the spores, so although present, they will not be viable. It is usually of some benefit to add an inoculum of mycorrhizal spores to the final tea solution when the tea is to be used for soil drench or root applications. The food resources present in tea may cause mycorrhizal spores to germinate after a few days, but if the germinated spores do not find active roots within 24 to 48 hours of germination, they will die. Therefore, spores should be added to the tea just before application to the crop.

Species Composition of Bacteria, Fungi, Protozoa and Nematodes in tea is dependent on diversity in the compost. If there is poor diversity in the compost, the tea will not give the benefits that would result with a healthy diversity of species. Healthy compost has been hypothesized to have between 15,000 to 25,000 species of bacteria per gram, but the DNA analysis required to establish the set of species in highly diverse compost versus the number of species in not-highly diverse compost — or compost tea - awaits further work.

In a study using plate methods, performed by the Soil Microbial Biomass Service (SMBS), every morphological type and every species that occurred in compost was found in the compost tea. Some of the bacterial species extracted will grow in the tea solution, provided the correct food resources are added or present. It is unlikely, though, that all the food resources for all bacterial species will be present in even the best compost tea solution. Therefore, this is a selective step. It is important that the food resources in the tea are selected for beneficial species, and not pathogens.

Diverse sets of bacterial species will control pathogen growth. Most pathogens cannot compete well with beneficial species. Therefore, by maximizing bacterial and fungal species diversity, selection will be against the growth of pathogenic and pest species.

In the study performed by SMBS, fungal species and biomass were found in much smaller quantities in the tea than in the compost. Extraction efficiency for fungi was not great using tea-making methods. In addition, the fungi extracted did not grow well in tea because they were shattered and killed by mixing and agitation. All protozoan and nematode species found in the compost were found in the tea (SMBS study, 1993).

Compost Tea Standards

The desired MINIMAL ranges for the different organisms in a standard tea are based on their ability to prevent the growth of other organisms on the leaf, stem or root surface. In order to cover the leaf, stem or root adequately, 5 gallons of tea should be applied per acre, and the organisms should survive the application, and should have foods to begin to growth. If disease is already present, it may be necessary to displace the disease through the mechanisms of competition for space, food, or infection sites. There is little evidence that antibiotic or toxic-compound production is a major, or even important, mechanism. Therefore use of the term bio-pesticide is probably NOT appropriate for the mechanisms by which compost or compost tea has it s major, or most important, impacts on disease.

Table 1. The desired minimal ranges for the different organisms in a standard tea.

Production Method	Brew Time	Temperature Above Ambient	Active Bacteria	Total Bacteria	Active Fungi	Total Fungi	Protozoa (see below) F, A, C	Nematodes (see below)
Desired Range	As short as possible	No more than 5-10° F	10-150 µg	150-300 µg	1-10 µg	2-20 µg	1000, 1000,50	2-10 B, F, P

µg means microgram, or one millionth of a gram. A gram is about one teaspoon
Protozoa column: F = flagellates, A = amoebae, C = ciliates
Nematode column: B = bacterial-feeding nematodes, F = fungal-feeding nematodes, P = predatory nematodes, Root-feeders should never be found in a good, aerobic compost

Variability from tea-to-tea, given that compost type, mixing, recipe used, etc. are the same, do not vary more than 10% for bacterial and fungi, but may vary up to 20% for protozoa. Note that for ciliates, there a level which organism numbers should not exceed**. Ciliates should not be greater than 100 individuals per ml of tea, as this would indicate limited oxygen conditions (anaerobic) in the tea.**

Tea can be diluted if the biomass of all categories will be within desired ranges AFTER dilution is complete. If the biomass/numbers are lower than the desired range, the amount of tea sprayed will have to be increased from the 5 gallons per acre typical to achieve the desired coverage.

In all the studies performed the organisms must occupy AT LEAST 65% to 75% of the surface.

In terms of leaf coverage the desired ranges are 60 to 70% for bacterial coverage, and 2 to 5% fungal coverage.

Comparison of Different Brewing Methods

In this section, teas were made in the different tea making machines either on site by SFI technicians, or the tea was made by the manufacturer and the tea sent to SFI for analysis. When performed at SFI, a standard compost composed of 50% thermal compost and 50% vermicompost was used. Lab conditions were maintained at 72° F, using de-gassed Corvallis city water as the water resource. The machines were run using the manufacturer s directions.

The compost was mixed well before use, measured out into the amounts needed for each machine, placed in the unit, the same amount of molasses and soluble kelp per volume of water added to each machine. Each machine was run for the specified time (indicated in Table 2).

Three sub-samples of tea were removed from the machine, typically via whatever method was available to move tea from the tea-making machine into the spray tank of a sprayer. If there was no pump to discharge, this is noted.

Each sample was assessed for total and active bacteria, total and active fungi, protozoa, and nematodes.

The composts used typically contained between 10 and 30 μg active bacteria, between 100 to 150 μg bacteria per gram dry weight of compost, between 15 to 45 μg of active fungal biomass, between 150 and 175 μg of total fungal biomass per gram, 4,500 to 20,000 flagellates, 30,000 to 54,000 amoebae and between 35 and 75 ciliates per gram. Nematodes varied from batch to batch of compost, between 20 and 45 nematodes, consisting of mostly bacterial feeders, several fungal-fungal feeders, switcher nematodes and on occasion, predatory nematodes.

The data from the tea that each machine made should be first compared with the compost from which the tea was made. If nematode, protozoa or fungal biomass was low in the compost, that may explain poor biomass or numbers in the tea. Remember, however, that bacteria may increase by 100 to 500 times the original number during a brewing cycle, while fungi may only increase by 5 to 10 times. Protozoa and nematodes DO NOT increase in numbers in a tea cycle. Their life cycles are longer than the duration of a compost tea brew cycle.

If the organisms are present in the compost, but not present, or low, in the tea, then the reason for the lack of those organisms in the tea is subject to assessment. Were the organisms extracted? Were they killed by too much pressure going through a pump? Did they not grow adequately in the tea? Did they lack food? Did they lack a surface to grow on?

As an example of an unforeseen problem, compare the result from the Microb-Brewer year 2000 test with the Microb-Brewer year 1999 test. In the year 2000 test, this machine had significant bio-film formation in the pipes, resulting in poor organism numbers in the tea because of anaerobic conditions that develop, and toxic materials produced by those anaerobic organisms. The Microb-Brewer 1999 tea, without any bio-film formation in the pipes, clearly made outstanding tea. For this reason, the pipes that used to occur on the bottom of the Microb-Brewer were replaced with clear plastic tubing, so users can see when a bio-film is forming. The solution is easy: Use a long-handled brush to clean the bio-film out of the pipes at the end of the run. Cleaning ANY tea-making machine, not just the Microbrewers, is a VERY important step in equipment maintenance.

The following table shows results from replicated trials with the Bubbler and the Trough methods. Clearly, the tea produced is not within the desired ranges, and there fore, quite often, does not protect surfaces from disease organisms, does not introduce the desired organisms to jump-start nutrient retention, or nutrient cycling, or to build soil structure or consume toxic compounds, such as anaerobic metabolites.

Table 2. Comparison of Microbial Numbers Using Bucket Bubblers and Trough Brewing Methods. Microbial populations in tea produced by different methods. Same quality compost, starting materials (1% molasses, 1% kelp), brew time as indicated.

Production Method	Brew Time	Temperature Above Ambient	Active Bacteria	Total Bacteria	Active Fungi	Total Fungi	Protozoa (see below) F, A, C	Nematodes (see below)
Bubbler	3 Days	1-2° F	None Detected	1 µg	None Detected	10 µg	100, 25, 0	1 B
Trough	3 Weeks	No Increase	None Detected	1 µg	None Detected	None Dete-cted	0, 0, 2000	5 B
Desired Range	NA	NA	10-150 µg	150-300 µg	1 - 10 µg	2-20 µg	1000, 1000, 50	2-10 B, F, D

Protozoa = F stands for flagellate numbers, A for amoebae numbers, C for ciliate numbers
Nematodes = B stands for bacterial-feeder numbers, F for fungal-feeders, R for root-feeders, and P for predatory nematodes (beneficials).

Compost Tea Production Methods

In all production systems, a biological film of microorganisms, called a biofilm and sometimes much thicker than a film (up to an inch or more in thickness in some systems), develops on surfaces. With time, the deepest layer of the film becomes anaerobic, resulting in production of strong organic acids that can kill organisms in the tea, kill plant tissue if applied to them, and can etch the tea-maker s surfaces. If the surface is metal, the metal will be solubilized and end up in the tea solution. For this reason, a metal container is not recommended. If brew time is short, and the unit is cleaned to remove the biofilm between brews, there will be little problem. Wood or plastic containers are preferable because they can be easily cleaned.

Bucket Method. Bucket methods date back to early Roman, Greek and Egyptian times (Brehaut, 1933 Cato s De Agricultura, Varro s Rerum Rusticarum Libri Tres). Many versions of compost in a bucket are still used today. Typically, the compost is either free in the water (which means that the non-soluble chunks have to be strained out of the tea if you want to put it through a delivery system) or suspended in a sack or bag, along with other non-soluble ingredients.

Fill the bucket half-full with water and stir vigorously for 10 to 20 minutes to de-gas any chlorine. Add the compost until the container is full, within an inch of the top for stirring to occur. Stir periodically with a stick, which mixes the solution as well as adding a small amount of air. Brew times need to be several weeks long, in order to get any of the organisms extracted from the compost. A few organisms will grow, but biofilm formation on surfaces is not usually that great, because there isn t much food for the organisms in mature compost and the bacteria won t grow rapidly enough to use up oxygen more rapidly than it can diffuse into the water. Molasses or sugar can be added, but in tea that is not aerated, this typically causes the tea to become anaerobic.

Immature compost can be a problem, however, and can result in highly anaerobic teas. After brewing, the solution is strained and applied to the crop (see Application Methods on page 18). These are typically the production methods from which we hear reports about the tea killed our plants , because poor compost, anaerobic conditions develop or toxic materials are extracted into the tea.

Bucket-Bubbler Method (based on work by Pat Battle at Highland Inn, Ashville, NC, and summarized by E. Ingham in Kitchen Gardner, Oct/Nov 2000). A more modern version of compost in a bucket is one used by many homeowners and backyard gardeners because small quantities can be made inexpensively. This is not useful at a commercial level however.

On the bottom of a 3 to 5 gallon (15 to 20 L) bucket, tape (waterproof tape, please!) air stones or bubblers attached to an aquarium-type pump. Fill the bucket half-full with water and bubble air through the water for 10 to 20 minutes before adding the compost. Add compost to fill bucket to nearly the top, with enough space for bubbling (DO NOT compact the compost or extraction will be poor and the tea may also go anaerobic). Add molasses or another food source for bacteria or fungi, as desired, but realize that the amount needs to be kept minimal, or growth of bacteria and fungi will use oxygen in the air faster than the aquarium pump can replace it. The aerator provides a continuous flow of air and creates enough turbulence to provide mixing. Still, in most cases, an occasional brisk stir helps the quality of the tea, by removing the organisms from the surface of the organic matter.

Brew for 2 to 3 days, minimum. Longer is ok. Then turn the aerator off and let the brew settle for a half-hour until most of the solids are on the bottom of the bucket. The soluble portion of the tea can be decanted from the top, leaving the insoluble solids to be returned to the compost pile. If the tea is used in a backpack sprayer, it may be necessary to strain the tea through cheesecloth, or a fine mesh tea sieve to prevent plugging the sprayer nozzles.

Trough Method. In this version, compost is suspended on a wire tray over a large tank of water, for example an old horse trough - thus the name of the method. Water is pumped from the tank, sprayed over the compost, and allowed to drip through the compost, like water through coffee grounds, into the tank. The trough can range in size from 5 to 500-gallons (20 to 2000 L). The brewing period generally has to be quite lengthy, because organisms are not extracted very well from the compost — not enough energy is applied to the compost to physically remove the organisms from the compost. Because the water is sprayed onto the compost, UV light kills many of the organisms in the water droplets if the unit is outside. Evaporation can be a serious problem, concentrating salts in the tea. As the water drops fly through the air before impacting the compost, oxygen diffuses into the drops, but typically not enough to maintain enough oxygen in the tea if molasses, sugars, humic acids, or some other food resource for the bacteria or fungi is added. Aerators are often used to supplement air diffusion into the water. Nutrients are of course extracted from the compost, and that benefit to plant growth can be significant.

Bio-films typically form on trough surfaces, especially in the corners of the tank and can result in amazing smells for a portion of the brew cycle while the few bacteria that are extracted grow rapidly in the tea. It would be better to use round-bottom containers. However, diversity of bacteria and fungi is typically quite limited in these teas. But these teas are not likely still anaerobic when applied on plant material, if the brewing has gone on long enough.

Commercial Tea Makers.

Soil Foodweb Inc. will test commercial brewers as they appear on the market and report on the quality of those teas relative to the biological life in the tea. Not all tea-making machines have been tested under all conditions, and sometimes as machines age, surprises are encountered. Testing under your local conditions, with your own water source, own composts, and starting materials is always recommended.

A number of new compost tea machines are/will soon be on the market. We have seen consistently good to outstanding tests of tea quality from these machines, dependent on the quality of the compost used, but field testing with a variety of customers using the machines is not yet available:

1. **Compara** Xtraktor , variety of sizes from 3 gal to 1000 gal, air pump variety , good extraction of all organisms, application rate of 5 gal/ac, contact: Gerben Schrouten, office@compara.nl.com
2. **Classic Nursery** Keep It Simple tea maker , 5 gallon size, air pump variety, excellent extraction of fungi, other organisms, applicaiton rate of 5 gal per acre, contact Leon Hussy, classicnursery@msn.com
3. **Earthworks** tea maker, activator for the tea recipe available, 5 gal/ac application, contact Joel Simmons, www.soilfirst.com
4. **Freedom Organics** tea machines, excellent extraction, 2.5 to 5 gal/ac, contact Scott Schaible, info@freedom-organics.com

SoilSoup machines have previously been included in this manual, but at this time have not been shown to give consistent results. Generally, our data indicate that between 85 and 100 gal/ac of tea are needed to obtain organism numbers which will cover leaf surfaces enough to exclude disease organisms. For this reason, promotional literature is no longer included in this manual for these machines.

Table 3. Extraction Using the BioBlender. Aerobic, fungal-dominated compost, starting materials 1% molasses, 1% kelp, brew time as indicated.

Production Method	Brew Time	Temperature Above Ambient	Active Bacteria	Total Bacteria	Active Fungi	Total Fungi	Protozoa (see below) F, A, C	Nematodes (see below)
BioBlender™	2 Days	1-5° F	0.1 µg	50 µg	5 µg	12 µg	100, 135, 2000	None Detected
Desired Range	NA	NA	10-150 µg	150-300 µg	1 - 10 µg	2-20 µg	1000, 1000, 50	2-10 B, F, D

Protozoa = F stands for flagellate numbers, A for amoebae numbers, C for ciliate numbers
Nematodes = B stands for bacterial-feeder numbers, F for fungal-feeders, R for root-feeders, and P for predatory nematodes (beneficials).

Growing Solutions Systems without aerators in the compost baskets typically require 30 to 50 gallons of tea per acre to give the desired coverage of organisms on leaf surfaces. Addition of aerators to the compost basket results in higher extraction so only 10 to 20 gal tea per acre are required. Addition of special aerators to the baskets can improve organism extraction so only 5 gallons of tea per acre are required.

Many homeowners and gardeners have found good disease suppression when they drench their leaves with tea, regardless of type of machine. If high quantities of tea are applied, 100 gallons or more to the acre, even tea that doesn t have acceptable numbers of organisms in 5 gallons can cover leaf surfaces and suppress disease. Putting out many, many gallons of tea per acre is not highly practical over large acerage, however.

The Microb♦Brewer - Applications

There are a virtually unlimited number of applications for the Microb-Brewer in sustainable agriculture, orchards, vineyards and all industries that work with plants, like landscaping, garden centers, nurseries and golf courses:

- Aerobic Compost Tea
- Foliar sprays with plant specific ingredients, metabolized by the microorganisms, providing the optimum absorbable plant food
- Pro-biotic foliar sprays, to occupy the leaf surface with beneficial microorganisms
- Root feed applications with plant specific ingredients, metabolized by the microorganisms, providing the optimum absorbable root feed by irrigation systems or manual application systems
- Improve soil activity by inoculation with a soil drench by irrigation systems or manual application systems
- Multiply commercially available microorganisms in virtually unlimited quantities (Do not use patented products!)
- Food-solutions for hydroponics, plant-ready, metabolized by the microorganisms

Foliar and root-feed applications can be prepared by adding the desired ingredients into the food-solution, customized for the specific application. The process of multiplying aerobic microorganisms starts by aerating food-solutions with the Microb-Brewer**.**
Because the high aeration rate, microorganisms start to multiply very rapidly and metabolize nutrients in the food-solution in less than 24 hours. Just as in nature, microorganisms prepare available nutrients for plants - the Microb-Brewer mimics this process, on an industrial scale.

There are many others applications where aerobic bacteria or fungi can be used:

- Compost Recycling
- Bio-Remediation
- Food-Production

Please visit the website at www.microbbrewer.com or e-mail at info@microbbrewer.com

Table 4. Extraction Using the Microb♦Brewer. Similar quality compost, starting materials (1% molasses, 1% kelp), brew time as indicated.

Production Method	Brew Time	Temperature Above Ambient	Active Bacteria	Total Bacteria	Active Fungi	Total Fungi	Protozoa (see below) F, A, C	Nematodes (see below)
Microb♦ Brewer (2001)	20 Hours	5-10° F 3-6° C	96 µg	536 µg	12.5 µg	21 µg	2,250, 1,679, 145	43 B, 2 F, 3 P
Desired Range	NA	NA	10-150 µg	150-300 µg	1 - 10 µg	2-20 µg	1000, 1000, 50	2-10 B, F, D

Protozoa = F stands for flagellate numbers, A for amoebae numbers, C for ciliate numbers
Nematodes = B stands for bacterial-feeder numbers, F for fungal-feeders, R for root-feeders, and P for predatory nematodes (beneficials).

The Microb♦Brewer™

Aerobic Culture Unit for Microor ganisms

The Microb-Brewer is a device designed to cultivate (multiply) aerobic microorganisms on an industrial scale. There are 3 parameters that are paramount to propagate, select and to grow the desired kinds of aerobic microorganisms.

1. The right food
2. The right temperature
3. The provision of air (oxygen)

<u>The basic components of the Microb-Brewer are:</u>

- Tank
- Pump
- Vortex-Nozzles
- Compost-Leach-Basket

<u>The current available sizes of the Microb-Brewer are:</u>

12 gal or 50 Liter
50 gal or 200 Liter
500 gal or 2000 Liter

The tank should be filled from a good water source (no chlorine, neutral pH), and then the soluble ingredients for the specific set of microorganisms desired are added to the water. Next, the inoculants or a high quality compost or, as the third option, both together should be added to the compost basket. The Microb-Brewer recirculates food solution from the tank through the pump, into the Vortex Nozzle and is returned to the tank. Inside this special Vortex nozzle, air is entrained into the food solution.

The Microb-Brewer maintains a highly aerobic situation in the brewer at all times, enhancing microbial growth to the point that processing time is below 24 hours (about 20 hours usually to attain peak organism numbers), depending on the size of the brewer. This allows continuous, daily production and thus a highly effective, productive and therefore economical and profitable investment.

Please visit the website at www.microbbrewer.com or e-mail at info@microbbrewer.com

Compara Xtractor

Our Xtractor can be utilized in all agri- and horticultural application including sports turf, garden center, golf course and nursery management

Features include:

1. Easy DIY design
2. Cost effective...!
3. Highest possible aerobic extraction within in 24 hours
4. Easy Maintenance
5. NO compost baskets
6. Simple but sustainable non-recirculating design
7. Very easy cleaning
8. No unnecessary assembly cost. Make it as sturdy as you wish and last but not least
9. Easy adaptability and room for innovative modification
10. Aeration Technology

To make quality aerobic compost tea it is imperative to maximize the Biological Oxygen Demand of the compost inhabitants. In our New Generation Xtractor technology we apply fine bubble diffusion technology. Thus we have cracked the impediments and short comings of systems that recirculate the tea through pressurized systems.

The Xtractor 2 is the right size for small operations in any agri-horticulture related business. It is very affordable and comes as a DIY Kit that can be shipped worldwide within 1 week. Easy to assemble it comes with a full set of instructions and is ready to operate within 30 minutes.

Xtractor 2 Specifications

Power	Single phase 220 V adaptable to local voltage
Tank Capacity	200 litres/50 gallons
Weight	30 kg
Height	120 cm
Xtraction Time	18-24 hours
Tank Volume	350 liters
Xtraction Vol.	200 liters
Covering	4 hectares at 50 litres per ha

Xtractor10 makes a royal 1000 liters tea for the least possible investment. This model is sold as a DIY Kit and contains all items to build the machine, but for the tank. The tank is bought locally according to specification and may be new or second hand. This allows for the utmost flexibility. Machine for mid-sized farming and greenhouse operations as well as golf-courses.

Xtractor 10 Specifications

Power	Single phase 220 V adaptable to local voltage
Tank Capacity	1000 litres/250 gallons
Weight	20 kg
Xtraction Time	18-24 hours
Tank Volume	min. 1250 liters
Xtraction Vol.	1000 liters
Covering	20 hectares at 50 litres per h

Xtractor 20 makes a royal 2000 liters tea for the least possible investment. This model is sold as a DIY Kit and contains all items to build the machine, but for the tank. The tank is bought locally according to specification and may be new or second hand. This allows for the utmost flexibility. Machine for large scale farming and greenhouse operations.

Xtractor 20 Specifications

Power	Single phase 220 V adaptable to local voltage
Tank Capacity	2000 litres/500 gallons
Weight	40 kg
Xtraction Time	18-24 hours
Tank Volume	2250 liters
Xtraction Vol.	2000 liters
Covering	40 hectares at 50 litres per ha

All DIY kits come with complete set of instructions. All that is needed is a tank.

Easy and cheap overseas shipment brings these brewers within the reach of anyone interested in tea developments. And that is Xactly what we wanted to achieve.

Compost Tea Ingredients

As the ingredients used in the extraction process eventually determine the quality of the brew, Compara selected different ingredients that are conform the highest standards. These are available separately in handy and user-friendly packaging. Compara initiated the development of pre-packed nutrients for the Xtractor. We specially select for easy to use, clean and dry materials of the highest quality, that make application easy and errors impossible.

These ingredients nourish the demands and appetite of the compost micro-life that is temporarily inhabiting the tea.

But all important is the quality of the compost used. Compost being our main business for many years, and research a matter of fact, we use a blend of our finest Compara Humus Compost, made according to the deep insights of Ehrenfried Pfeiffer and Vermi compost. To further increase diversity we add the finest smelling compost we are able to produce by means of a specialty compost starter. Combined with our ingredients, of which none is pre-packed, we insures the finest possible quality.

Please call or email www.compara.nl.com for more information

Application Methods

Compost tea, with the right set of organisms present, can be applied with water in any of the many ways water is applied; through irrigation systems of any kind, through sprayers or through hoses. The important point is that the tea cannot contain particles which will clog the water delivery system, and therefore must be properly screened to pass through the spray nozzles, sprinkler heads, drip irrigation lines, emitters, etc.

Sprayers are ideal for applications of tea onto leaf surfaces. Sprayers range from tractor mounted models for large acreage to simple backpack versions. When applying compost tea to leaf surfaces, the key is getting at least 70% of the leaf covered with the tea organisms - **on both sides of the leaves**.

Tea can be applied to foliage as a foliar spray - typically at 5 gallons to the acre (50 L /Ha) per 1 to 5 feet of plant canopy, once per growing season, every two weeks, or when needed to occupy leaf surfaces and compete with organisms. Coverage of leaf surface is the critical measure. It should be clear that if organisms are delivered to leaf surfaces at a too high velocity, the organisms will smash into the leaf or stem surface and disintegrate. This means they will not be present to protect the leaf surfaces or occupy infection sites instead of the disease-organisms.

Tea can be applied to soil as a drench, typically at a pint to a quart per plant of undiluted tea. Additional water can be used, but the point is to apply enough organisms to inoculate the soil around the root with a good set of organisms. Tea can also be applied to drench the soil surface, typically 5 gallons to the acre (50 L/Ha) in whatever amount of water is desired.

Other methods of root zone feeding vary from simple hose-end sprayers to elaborate drenching systems that dose each plant with a pre-measured amount of solution to injection systems. It should be clear that, with injection systems, the pressure applied cannot smash the organisms into the soil particles, or all that is delivered is cytoplasm soup as the organisms impact on the soil particles and disintegrate.

Recall that tea should be applied before 10 am or after 3 pm on sunny days because UV can kill organisms as they fly through the air. Do not apply tea when it is raining hard, but a light mist often helps the organisms establish a foothold on the leaf. Tea should not be applied with greater than 40 to 80 PSI of pressure, and should be applied during weather when plants are active. This means starting at two weeks before bud break, through to senescence of all plants in late fall in temperate zones, and in tropical areas, when the plant desired needs protection.

Tea should be applied as a mist, so the liquid will remain on the leaf, stem and flowers of the plant, and not drip off. The larger the drop size, the more likely the tea will run off the plant. Low volume sprayers with moderate pressure are the best suited for this type of application.

How Long Can Tea Be Held? This is an area currently being researched. When the first commercial brewer (Microb-Brewer) was released, testing indicated that tea needed to be made and then used. With further testing, however, highly active organism teas (such as given in Table 1, Desired Range), show that if the tea is well-aerated, with maximum levels of oxygen in the tea, and the organisms have used up most of the easy-to-use food resources, then the tea will remain aerobic for 6 to 8 hours (work performed by Lynn Rogers, Soil Foodweb Inc., Fall 2000). After 8 hours, aerobic activity falls rapidly, most likely resulting from the lack of oxygen in the liquid.

If, however, the liquid is kept aerated, then holding time can be increased, up to three days, although numbers of active and total organisms falls off at an ever-increasing rate. At the end of three days, a ten-fold reduction in numbers, and a 90% reduction in activity occurred (work performed for ARDEO, Inc. 1995). This is acceptable for a soil application, but not for a foliar application. Active organisms are a necessity for foliar protection.

If bacterial and fungal foods are added to the tea at 48 to 72 hours, depending on the number of active organisms, and how much food was present in the tea recipe to begin, and probably the number of organisms extracted (this has not been tested in other words), then the activity of the organisms can be extended. By the end of five days total, however, a serious reduction in diversity of the organisms always occurred in the teas examined, so it is considered that these teas would be less likely to benefit plants than younger, more diverse teas. Again, this testing remains to be performed in a scientifically sound fashion.

Addition of foods to tea can help maintain shelf life of a tea, but aeration must be continued. Any large tank with aeration can be used to hold the tea, but adding food resources will likely outstrip the ability of the aeration to maintain aerobic conditions. The best thing is to keep the tea in the maker, and continue the aeration if it becomes necessary to add food to maintain activity of the organisms in the tank. Recent work (within the last 6 months with the Microb-Brewer) showed that addition of fresh compost and additional nutrients to the existing tea at 12 to 24 hours, along with continued maintenance of aeration, would allow continued organism activity for another brew cycle of 20 hours.

Two more recent tests however, showed that despite maintenance of aeration and good mixing, both total and active bacterial as well as total and active fungal biomass fell precipitously within 48 hours. Further work is needed to assess these observations. Most likely, though, trough and bucket methods allow tea to be held for a long time, since organism numbers and activity are limited in these systems.

Plate count assessments cannot be used to determine this kind of information since plate counts allow spores and dormant individuals, as well as active organisms to grow. In fact, in a recent test, leaves that contained very few active organisms and leaves that contained a high number of active organisms gave the same plate count numbers. This is because very few of the organisms that live on leaves grow in any plate count medium. During the incubation of the plates, dormant individuals, including spores, came to life on plate media, and a similar number of spores appeared to be present on each set of leaves.

Certain materials can be added to teas to push the organisms into dormancy. There are no data available to suggest if many or few species of bacteria or fungi are killed, inhibited or lost when this is done, but is likely that diversity is significantly limited by this treatment. The organisms in a tea MUST be dormant if the tea is bottled, or the respiration of the organisms would cause the bottle to explode. Thus, teas which are put-to-sleep are better for soil applications, because the or ganisms have time to wake up before they have to start to function, whereas on leaves, the organisms must be immediately active to protect the leaf surface.

Preventative Applications. Typically, applications for preventative control of foliar and soil diseases are 5 gallons of undiluted tea per acre (50 L/Ha) every two weeks, starting at two weeks before bud break and continuing until all danger of loss of crop yield due to disease is past. If disease is observed, make an undiluted tea and spray it immediately onto the affected areas, drenching the area. Typically this has resulted in significant competition of the tea organisms with the disease and the disease has been consumed or out-competed. In a few cases, when the infestation was severe, repeated application was required to bring back the condition of health.

For preventative applications, the 5 gallons (20 L) can be diluted in however much water is desired, as long as 5 gallons per acre (50 L/Ha) is applied. Tea must be applied to both top and bottom of leaves, blossoms, steams, etc, or sprayed directly into the top layer of soil. Recent work by John Buckerfield in Australia indicates that coverage with a mulch layer improves organism survival (most particularly earthworms if they are applied in a worm compost) and increases the benefit of single-applications.

Control of Existing Disease Conditions. To control **already existing foliar diseases**, generally the infected foliage has to be drenched with **undiluted** tea every three days until the disease is controlled.

If the disease is not a foliar pathogen, foliar applications will not be successful. Tea is not a panacea that will cure everything. The mechanism for control has to be understood, and tea correctly applied to deal with the CAUSE of the problem.

For example, in the author s yard, admittedly not a replicated study, but still of interest, a single application of undiluted tea was made to the roses in her yard on May 15, 1999. No black spot or mildew was observed throughout the summer, in fact, none until mid-July, 2000, a full year and three months after the single application. The author s yard receives no pesticide or inorganic fertilizer applications, which may be a reason that a single application was effective for more than a year. But mildew was noticed on the roses in July 2000. A single application of un-diluted tea immediately applied slowed the mildew down, but did not get rid of it. Three days later, a second application was made by drenching the infected areas with undiluted tea, and still, the problem was not controlled, although there was no spread of infection. A third application of undiluted tea, again, three days later controlled the mildew to the point that no visible symptoms were apparent. Already wilted leaves could not be brought back to life and were removed. This suggests that even once disease appears, by concentrating applications of organisms on infected, but not yet dead areas, recovery is possible, but not guaranteed. A great deal more work needs to be done to fully understand the mechanisms of control. Steve Schuerell (Oregon State University, Dept. of Botany and Plant Pathology) is performing a controlled, scientifically replicated study on black spot in roses, and these data should be published when he finishes his thesis.

Soil Applications. To prevent soil diseases, a sample of soil must be taken and the foodweb assessed. Then, make a tea that is appropriate to return the missing organism(s) to the soil and apply at 5 gallons to the acre (50 L/Ha). After 2-4 weeks, take another soil sample for analysis to make certain the organisms survived application to the soil (total biomass gives this information), and they had food to stay alive (activity gives this information). If the organisms are not present, a chemical residue is indicated, and needs to be remediated. Apply a tea with organisms that will degrade common pesticide residues, with the foods those organisms require to decompose resides, such as the High Bacterial Tea recipe. If the right organisms are present, but not active, then only the specific foods are needed, such as sugars for bacteria, or humic acids for fungi.

Making Compost Tea Appropriate to the Plant

The requirements of plants need to be recognized, at least with respect to the organisms that most benefit their growth and their special nutrient requirements. These needs can be met by applying compost and compost tea.

Compost and compost teas need to be defined relative to the specific plant and soil to which they are applied. Soil rich in organic matter with a healthy foodweb will suffice with a tea less rich in food resources than a soil lacking organic matter which will need a good set of beneficial microorganisms and food.

Compost, or more easily, compost tea, that will supply the organisms that do the work the plant needs. The plant will feed those organisms, and the micro- and macro- nutrients, that the plant requires, in a form that is easy for the plant to take up, can be provided to the plant through the foliage.

Compost and compost tea will increase the diversity of bacteria and fungi, protozoa and beneficial nematodes, even in soils high in organic matter soils. Just because a soil has lots of organic matter does not mean the full complement of organisms beneficial to the plant are present. Chemicals that kill the beneficial bacteria and fungi on the plant s leaves, stems and blossoms need a compost tea containing those microorganisms in order to replenish the plant s defenses. Similarly, a low organic matter soil will require a compost or compost tea with high numbers of beneficial microorganisms, as well as sugars, soluble kelp, carbohydrate material, humic acids and algal exudates to increase the food resources for the microorganisms.

Compost tea should contain nutrients to feed the bacteria and fungi, as well as micronutrients that the plant can absorb. Growers of plants, no matter how large or small the area, should ask, **What does the plant require in terms of nutrients, bacteria and fungi to protect the plant from disease-causing microorganisms?** To retain nutrients in the soil around the plant? To make those nutrients available back to the plant? To decompose any toxic or leftover residues that may be present in the soil? To build soil structure so air diffuses into the root zone and prevents fungal root rot diseases?

Table 3 answers these questions, as far as we know them, for four major soil types, and for major plant groups. Always consider, however, that you need to know something about the soil in your area. For example, if the soil is high in humic acids and other recalcitrant materials (those resistant to decomposition or decay, such as woody materials, bark, straw, old manure, oak leaves or conifer needles), then the soil is likely to be fungal-dominated, regardless of sand/silt/clay ratios. In this case, the recipe chosen should enhance bacterial biomass in order to balance the fungal-to-bacterial biomass ratio. Conversely, if the organic matter in the planting medium is not slow to decay (e.g., green residues, green leaves, fresh manure), then the tea recipe should be one that selects more for fungal biomass, again, to balance the fungal-to-bacterial biomass ratio.

Table 7. Food Resources for Different Organism Groups.

Product Name/Company	Group Fed	Application Rates per 50 Gallons (200 L) Tea
REM and Hydra-Hume/ Helena Chemical Company	Fungi	600 ml (1 pint) to 4L* (1 gallon)
Blend/Huma-Gro Inc.	Bacteria (some fungi)	600 ml to 4 L
LASE/Huma-Gro Inc.	Fungi (some bacteria)	600 ml to 12 L (3 gallons)
Yucca/Desert King or Helena Chemical Company	Bacteria and Fungi, soil flocculant	600 ml to 4 L (1 gallon)
Vitazyme/ Vital Earth Resources	Fungi	1 to 4 ounces
Various sugars (fructose, sucrose, fruit sugars)	Bacteria	1 oz (28 g) to 1 lb (450 g)
Fruti Pulp	Sugars for bacteria, solids for fungi	1 US pint (0.45 L) to 1 gallon (4 L)
Proteins (liguified fish, alfalfa meals, oils)	Fungi	Test in your system
Yeast (brewer's, baker's, wine, champagne)	Contains complex mix of proteins, vitamins, minerals for both bacteria and fungi	Test in your system

*1 US gallon = 3.8 L, or round up to 4 L

The balance of fungi to bacteria must be viewed with respect to the needs of the plant. For example, trees require a fungal-dominated soil, while row crops and grass need an equal balance of fungi to bacteria. Based on the limited testing that has been done, we have determined that teas applied to foliage should always be bacterial in nature.

The Right Compost. It is critical to start with compost or vermicompost that will produce the desired microbial balance. If the tea needs to be more fungal, compost high in fungal biomass should be chosen. Generally, compost high in volume of woody material (resistant to rapid decay) will probably be fungal-dominated. A typical

fungal compost recipe contains 25% manure, 30% green material and 45% woody material.

Fungal composts typically need less turning because the chunkiness of the woody material allows better air diffusion, and because the high heat in a compost pile comes from the metabolic heat produced by the growing bacteria. Thus, piles with more woody material typically do not reach temperatures above 150° F (65° C). Turning is needed only to homogenize the pile and spread the growing organisms evenly throughout the materials.

If bacterial tea is indicated, use compost made with 25% manure, 45% green material and 30% woody material (note that these relative ratios change as we learn what works best . Each composter needs to work the best combination out for themselves, with their own starting materials). The quantity and source of manure is important. The higher the level of N in the manure, the faster the pile heats. If too much N is present, the pile may heat above 180° F (85° C), and may combust. Turning becomes critical for cooling the pile and bacteria are selected as fungi are killed during the turning process.

Again, the size of the particles in a compost pile is important. If green or woody material is finely chopped, then the N in that material is more readily available to the microbes, the bacteria will bloom, increasing temperature and rapidly using up the oxygen. To prevent anaerobic conditions, compost with finely chopped material will require air to be pumped in or turned at least once per day.

The Right Foods. ADD NOTHING THAT CONTAINS A PRESERVATIVE!! What are preservatives? Anything we use to prevent microbial growth, such as antibiotics, chlorine, fumigants, sterilants, alcohol, benzoate, benzene, phenols, terpines, iodine, etc. When in doubt, ASK!

The appropriate supplement is often determined by which organism group(s) is (are) missing from the soil or foliage, or by which micronutrients are deficient in the soil and/or in the aboveground plant surfaces. Thus, plant tissue analysis can help greatly in determining which micronutrients need to be added to the tea for foliar application and micro-feeding.

Compost tea is often supplemented with simple sugars to encourage bacteria growth; and with soluble kelp and humic acids to enhance the growth of fungi. The set of microorganisms most beneficial for the soil will likely be different from the set of microorganisms most beneficial for the leaf-surface, but if you aren t sure what your plants need, make a tea that contains both sets of microorganisms and let the plant do the selecting.

The selection for the preferred microbial community, given a compost of say equal bacterial to fungal biomass, can be made by adding components to the tea solution before the tea brewing process begins. Additives that help bacteria most are simple sugars, syrups such as molasses, cane syrup, sugar beet syrup, spoiled carrot juice, apple juice from applesauce production, and yeasts (vitamin addition). Materials that help fungi more than bacteria are things like fruit pulp (the cellulose in the pulp generally helps fungi more than bacteria but bacteria will grow on the sugar portion of the pulp), soluble kelp (protein and micronutrients), humic acids, or other high cellulose containing pulp material. Plant extracts, such as comfrey, nettle or dandelion soups can also be added to enhance the micronutrient content of a tea. Anecdotal information from growers suggests that comfrey is high in Ca, N and K, and thus alleviates nutrient stress if plants lacking these nutrients. Comfrey has been chopped and added to the compost before it is composted, or after composting is finished (dangerous if there is any disease on the comfrey that could spread through the compost), to the compost basket during the tea brewing operation, or as a brewed soup (stuff a bucket full of comfrey leaves, add water, churn the leaves in the bucket for a day or so, then add the liquid to the water at the start of the brew process). In each instance, significant benefit to plant production was observed, most likely explained by improved Ca uptake by the plant. However, these were not replicated studies, and to fully accept this type of work, controlled scientific studies are required.

Michael Alms of Growing Solutions, Inc states that it is important to use a Norwegian or North Atlantic cold-water grown kelp, not warm-water grown kelp. Cold-water kelp absorbs and retains more nutrients during growth than warm-water kelps, resulting in greater micronutrient benefits.

Many interesting ingredients have been used in teas, but their benefit has rarely been documented. The special elixir that works wonders for one grower may have little or no benefit, or sometimes be detrimental, to your plants. The explanation lies in the biology and the chemistry of the plant, the soil, and the tea. The biology may have been right for your friend s squash, but isn t right for your indoor citrus tree. When in doubt, test the tea on part of the plant, or in a small area of your field.

The Recipes

The following recipes are based on 50-gallon (200 L) compost tea making machines. Ingredient amounts should be maintained at the same ratio per volume of water as in the following recipes, even if compost volume is not linear. The same amount of food per unit liquid is still required, regardless of the inoculum amount require (which is not linear; see below). With high amounts of sugar, make certain that adequate aeration is provided or the tea can become anaerobic within just a few hours.

There are two parameters to consider to use the Recipe Table (Table 9):

1. Category of plant that is closest to the one you want to grow,
2. Soil type that is closest to the four listed in the table.

For example, tomatoes are in the grass/row crop category, while strawberries, grapevines, kiwi, rhododendron, and snowbrush fall in the berry/vine/shrub category. Deciduous trees include poplar, almond, peach, citrus, coffee, apple, avocado and olive. Conifers include pines and most evergreens. It should be noted that some cedars actually fall in the deciduous category, and epiphytic plants and palms most likely fall in that category as well.

Table 8. Tea Recipes for Different Plants and Soil Types. See following pages for the precise recipe and processes.

Soil Type (parent material)	Plant Types				
	Broccoli, Cabbage (strongly bacterial)	**Row Crops, Grasses** (1/3 more bacteria than fungi)	**Fescue, Corn, Clover** (equal bacteria to fungi)	**Shrubs, Deciduous Trees, Vines** (2 to 10 times more fungal than bacterial)	**Conifers** (100 to 1000 times more fungal than bacterial)
Sand	High Bacteria Tea	Equal Ratio F:B*	Fungal Tea*	Fungal Tea*	Fungal Tea (mycorrhizal)
Loam	High Bacteria Tea	Bacterial Tea*	Equal Ratio F:B*	Fungal Tea*	Fungal Tea (mycorrhizal)
Clay	Bacterial Tea	Bacterial Tea*	Equal Ratio F:B*	Equal Ratio F:B*	Fungal Tea (mycorrhizal)

*Check mycorrhizal colonization of roots.

Most plants can be colonized by mycorrhizal fungi, except for strongly bacterial-dominated plants such as broccoli, most kales, cabbage, cauliflower (i.e., many brassicas). Most other plants either do better in low nutrient conditions or are obligately mycorrhizal. Thus, mycorrhizal colonization of roots should be checked by taking root samples from several plants and sending them into a soil biology lab (such as Soil Foodweb Inc., www.soilfoodweb.com, or BBC Labs Inc., www.bbclabs.com) to determine the percent of the root system colonized by mycorrhizal fungi. Deciduous trees require VAM inoculum, while conifers need ectomycorrhizal inoculum, or a combination of VAM and ectomycorrhizal fungi. Blueberry needs ericoid mycorrhizal fungi, but no inoculum of these mycorrhizal fungi is available commercially. In this case, or for other plants with limited species requirements, take soil from the surface near an existing healthy plant growing in a native system and use this as an inoculum.

Water versus Compost Volumes and Extraction Efficiency. This has been an area of intense examination recently, and there is new information here. Extraction efficiency DOES NOT relate, as thought earlier, to the volume of water used for extraction but rather to the efficiency with which the water pulls the organisms from the compost. Lower pressure is acceptable if, at the same time, the particles of compost move against each other and that friction removes the organisms from the compost. Thus, the compost has to be free to move in the container. Thus, a very small amount of compost might be acceptable, if the extraction conditions are optimal with respect to water flow THROUGH the compost, and movement of the compost in the container.

These recommendations were given in Edition 1 or the CTBM, but THEY ARE NOT NECESSARILY CORRECT given the current crop of machines with better extraction efficiencies, such as the Compara Xtraktor, or the EPM Earth Tea Brewer. We used to recommend 21 pounds (9 kg) of compost for 50 gallons (200 L) of water, 7 pounds(3 kg) for 12 gallons (50 L) of water, and 100 pounds for 500 gallons (2000 L) of water, but now the recommendations, wit hthe newer machines, is 15 pounds (7 kg) of compost in 500 gallons, 10 pounds (4.5 kg) of compost in 100 gallons, 5 pounds (2.5 kg) in 25 gallons and 1 pound (2 kg) in 5 gallon brewers.

Brewing Time. The brewing time must be long enough and/or have enough mixing to extract the desired soluble nutrients (food resources used by the microorganisms and micronutrients). If brewed too long, the microorganisms may go to sleep and not be active.

When to Add Materials.

Soluble materials should be added to the water at the beginning of the brew cycle, unless otherwise noted in the recipe. If mechanical parts can clog, non-soluble materials should be placed in the compost container. Mycorrhizal spore suspensions should be added to the tea at the end of the brewing cycle, not at the beginning, because the spores will begin to germinate in the tea after several hours. Mycorrhizal spores are sensitive to pressure just after they germinate and the pressure involved with mixing will kill them.

Commercial versus Indigenous Organisms. Indigenous microorganisms are clearly the best choice for any particular system, therefore develop beneficial microorganisms adapted to your conditions. One way to get the indigenous beneficial microorganisms into the tea is to add a pound of soil from highly productive soil or composts to the compost container. Be sure the soil has not had recent inorganic fertilizer or pesticide applications. If a tea turns out well, save a small amount to add as the inoculum for the next batch of tea to keep improving beneficial microorganisms and select against the not-beneficial ones.

Fine-Tuning Your Recipes. Specific quantities are suggested in the following recipes, but they are really only STARTING points. After testing one batch, modify the recipe to see whether a variation will work better with your particular plants, field, soil, climate, watering schedule, etc. Develop the best soil and foliar microorganisms for YOUR growing system.

Materials can be substituted, as long as they stay in the same functional category of material. Each compost tea maker is starting to make, or has been for quite some time, specific mixes of materials.

Recently Bruce Elliott at EPM (bruce@fish-world.com) has developed an outstanding mix of materials that give fungi a real shot in the arm, and gets them growing EXTREMELY well in the tea. He continues to do work on food resources for different kinds of beneficial organisms in the tea.

The following recipes are all based on 50 gallons of water, degassed if required to remove chlorine, checked for extraction of the compost (brown color released into brew before adding molasses or kelps).

High Bacteria Tea

20 pounds (9 kg) bacterial compost

16 ounces (500 mL) black strap molasses, or 32 ounces (1 kg) dry molasses

8 ounces (250 g) soluble cold-water kelp (additional proteins)

1 to 6 ounces (30 to 200 mL) liquid, filtered plant extract material (for example, yucca extracts, nettle soup, dandelion wine, comfrey tea), proteins, fruit juices, fruit pulp, fish emulsion

Add nothing with a preservative or antibiotic in it!

Concoctions that were brewed and become anaerobic can be added to recipes like this one that call for plant extracts, because the anaerobic decomposition products will be consumed and converted into aerobic, plant-beneficial compounds during the brewing process. Of course, the brewing process must remain highly aerobic, so use a machine or method that provides a high rate of aeration and thorough mixing. Dry molasses lacks a significant component of more complex sugars, so a greater amount of dry molasses is needed. There is less diversity of types of sugar in dry molasses as well, so use of a second type of sugar would be a good idea — such as corn syrup, maple syrup, or starch.

Bacterial Tea

20 pounds (9 kg) bacterial-dominated compost

16 ounces (500 ml) blackstrap molasses or 32 ounces (1 kg) dry molasses

8 ounces (250 g) soluble kelp

Optional: Additional proteins, fruit juice, fruit pulp, fish emulsion

Add nothing with a preservative or antibiotic in it!

This yields a moderately bacterial tea. Addition of kelp adds micronutrients and some bacterial as well as fungal food. Addition of several sugar sources can increase the species of bacteria able to find food in the tea and improve the ability of the organisms in this tea to occupy different habitats on leaf, blossom, stem or root surfaces.

Equal Ratio Fungi to Bacteria Tea

20 pounds (9 kg) 1:1 fungal to bacterial biomass ratio compost

1 pint (600 mL) humic acids

8 ounces (250 g) soluble kelp

Fish hydrolyzate, other proteins (see label on packages), fruit pulp

Add nothing with a preservative or antibiotic in it!

Humic acids select for beneficial fungi, but any fungal food could be substituted here. Make certain to obtain a mixture containing many humic acids, rather than a limited set (i.e., 3 to 5 humic acids). Rock dusts, rock powders, or rock flours can be beneficial as well, although these grainy materials can harm mechanical pumps. Fish hydrolyzates should be tested for their ability to serve as fungal food resources before using extensively. Fish emulsions do not have the oils that help fungi grow, so an emulsion is more beneficial as a bacterial food than a fungal food.

Fungal Tea

20 pounds (9 kg) fungal compost

1 pint humic acids (600 mL)

1 pint (600 mL) yucca, saponin, aloe vera (a high saponin content).

8 ounces (250 g) soluble kelp Fish hydrolysate, additional proteins

Add nothing with a preservative or antibiotic in it!

Make sure the compost is mature, has not been disturbed or turned for a week or more. Fungi retain Ca containing material. Comfrey leaves, pressed comfrey juice are also high in Ca. See Charles Walters book, Weeds - Control Without Poisons (ACRES, USA).

Mycorrhizal Inoculum, Fungal Tea

20 pounds (9 kg) fungal compost

16 ounces (500 mL) black strap molasses

1 to 6 ounces (30 to 200 mL) filtered plant extracts (for example, yucca extracts, nettle soup, dandelion wine, comfrey tea)

1 pint (60 mL) humic acids

8 ounces (250 g) soluble kelp (additional proteins and micronutrients)

Mycorrhizal inoculum — available from Mycorrhizal Applications or Plant Health Care

Add nothing with a preservative or antibiotic in it!

The concentration of spores needed has not been well established for different plant species. A range of 50 to 100 spores per gram soil is probably adequate to establish colonization. Since mycorrhizal spores germinate and begin to grow within a few hours of addition to most teas, add the spores to the spray tank, holding tank, injection system, etc. For row crops, vegetables, grass, most berries, shrubs, and deciduous trees, vesicular-arbuscular mycorrhizal fungi (VAM) are the mycorrhizal fungi of choice, while conifers and some late-successional deciduous trees require ectomycorrhizal fungi.

Leaf Organism Assay™

1. To determine the leaf coverage before spraying, pull a minimum of 5 leaves from different areas of the canopy of a plant or tree and place in a sealable plastic bag BEFORE spraying tea.
2. To determine whether leaf coverage by organisms is adequate after spraying compost tea, pull in minimum of 5 leaves from different areas of the canopy and place in a separate plastic bag AFTER spraying compost tea.
3. Copy a Leaf Organism Assay submission form from the Soil Foodweb website (www.soilfoodweb.com) or call 541-752-5066 for a form. Fill out information and send with samples.
4. Send overnight mail to Soil Foodweb, Inc. (address on submission form). Keep leaf samples separate from soil samples.

Is Compost Tea Doing the Job?

How do you know if the tea is good?

1. Smell and color. If it smells earthy, sweet, like soil, then it is likely a good tea. The color should be dark brown, like a good coffee.

2. Temperature. In machines where the tea goes through a pump, temperatures should increase by 5° to 10° F (2° - 5° C), as a result of friction in the pump and growth of the organisms in the tea. In machines where air is bubbled into the water to produce mixing, the temperature of the tea usually remains at air temperature. If air temperature is less than 72F (22C), the organisms in the tea will be too cold to properly reproduce in 24 hours, and the brewing time will have to be increased or the water heated.

3. Foam. Often indicative of a really good worm tea. You can reduce foaming by adding a spoonful or two of vegetable oil or yucca (a surfactant such as saponin, but choose one without preservative and one that does not contain anti-microbial compounds. Canola and Olive oils both often contain anti-microbial materials)!

4. Send a tea sample in to determine whether there is a good set of bacteria, fungi, protozoa and nematodes present in your tea. Check the Soil Foodweb website (www.soilfoodweb.com) for sample forms, prices, how to sample.

5. Send a sample of tea-sprayed leaves into Soil Foodweb, to assess whether the leaves were adequately covered with protective bacteria, fungi, protozoa and nematodes. Use the following information to collect leaves to assess adequate coverage.

6. Send a sample to determine Pathogen Inhibition. This assay determines whether the tea contains beneficial fungi and bacteria which, under the conditions in the lab, can kill a certain group of pathogens. Check BBC Labs (www.bbclabs.com) for prices.

7. Assays for specific groups of bacteria and fungi can also be performed using molecular methods.

Documenting GOOD Compost Tea

Make sure that the machine you buy can prove it has the capability of making good tea. Get a copy of their data. If you can t understand their data, FAX or e-mail it to SFI and we ll work with you to explain what it means.

Useful data for assessing tea:

1. A report showing that the organisms in the tea can inhibit standard plant pathogens. At least 75% of the pathogens tested should be inhibited.
2. A report showing that the DESIRED RANGE of both bacteria and fungi were produced in the tea. Without these biomass levels of organisms, there is no possibility that the tea can give you the disease suppression, nutrient retention, nutrient cycling, decomposition of toxics, or ability to build soil structure that you desire.
3. Oxygen concentrations through the brew cycle. Is the machine capable of aerating the tea even when the organisms in the tea are growing at the fastest rate possible.

In all these tests, the tea machine makers should state the conditions that they tested. Standard conditions shouold be: Documented aerobic compost, molasses, kelp. Molasses and kelp should be in the 16 to 32 ounce range. If the conditions of the standard test show huge quantities of sugars, then to get the same tea, you will have to add huge quantities of sugars.

Generally, the compost should NOT be above the waterline of the water in the tea tank, and should preferably be 2 inches below the waterline to allow good movement of the compost in the bag or basket.

Use blackstrap, food-grade molasses, and/or OTHER SUGARS. Typically, consider adding 0.5% sugar, for example, a half gallon molasses per 100 gal in the water at the beginning of the brew. A quart in 50 gal, a pint in 25 gal. When first starting, use about 0.1% kelp, or a handful per 50 gal.

Make sure the water is at room temperature (72 F) to start and stays at room temperature or above throughout brewing.

Make sure the water, if chlorinated, is de-gassed. Or add citric acid, about a half cup of the dry powdered Tang breakfast drink and good half hour before adding any compost.

Make sure the COMPOST smells sweet and earthy. NO stinky smells allowed. Check that the compost contains a good bacteria and fungi, as measured by an SFI test or a molecular fingerprint, for example. Test the machine the first three times you run tea to make sure you know the signs of a good tea in your specific conditions, and with your compost.

The Form

Record this information so you know what thequalitative materials and conditions were that helped you make a good tea. Based on the lab data from the first three runs showing that the tea is good, from then on use the qualitative measures - smell, color, texture, residue in the team maker, foam, etc.

Date: ______________________ Kind of Tea maker: ______________________

Water Volume used: ______________________

Type of Water Used: __________ Dechlorinated? ☐

Starting Temp: ______________________

Ending Temp: ______________________

Compost Used:

Smell: ______________________

Color: ______________________

Texture: ______________________

Recipe used:

☐ Molasses? How much? ______ Type? ______

☐ Kelp? How much? ______ Type? ______

☐ Humic Acid? How much? ______ Type? ______

Other ingredients: ______________________

Foam? ______________________

Smell of tea at end? ______________________

Color of tea? ______________________

Texture of tea? ______________ Any residue in tank bottom? ______________

Oxygen content at start? ______________________

at 18 hours? ______________________

at 24 hrs? ______________________

SFI results:

Active bacteria ______________________

Total bacterial ______________________

Active fungi ______________________

Total fungi ______________________

Pathogen Inhibition: ______________________

For help interpreting this, FAX or e-mail to: 541-752-5142, or info@soilfoodweb.com

Grower Experiences

The following is a selection of responses received from growers using compost tea. You can contact these people if you are interested. If you have experiences of your own to share, please send them to us at info@soilfoodweb.com.

Our main business is in landscaping, but we recently added or ganic compost tea spraying as a tool and service. We have had incredible results using tea made in the Microb-Brewer on a newly installed lawn. The customer was focused on finishing the front of their new home with a landscape. The backyard took last priority, so their decision was to do the minimum amount of work. We scraped the sight clean, put down 3 inches of topsoil, sod, and a heavy compost tea application the next day. There weren t any other amendments. After 20 days the sod roots were 8-11 inches long and had reached down several inches into the compacted native soil.

Kristin and Robert Rochholzlz
Creative Gardens, Inc
Coupeville, Washington
Iamkmh@aol.com

W e have been experimenting with compost teas, as a foliar feed, on our 130-acre orchard for the past three years. We have been using and recommend four to six applications per season for soil management. With this program we have noted the following improvements in fruit quality:

- Red Delicious apples have a deeper red color early season and are firmer at harvest. This past season we have also noted less decay after long-term storage.
- Jonagold apples, with mid-season to harvest tea applications, had as much as 25% more color than those that were not treated resulting in a significant increase in price per pound.
- Golden Delicious apples developed a red blush, increased firmness and more yellow color at harvest.
- Pippin and Granny Smith apples were firm at harvest and stayed firm throughout long-term storage.

We have also noted some general benefits that are not variety specific. Using multiple foliar applications, the apples do not drop prematurely, increasing our harvest yield. The elemental value increased in the fruit; i.e. fruits heat up faster internally, resulting in better color and less sunburn. We have also observed blushed fruit with foliar compost tea applications where it normally is not apparent.

Ron Stewart
Columbia Gorge Organic Fruit Company
Hood River, Oregon

With the Microb-Brewer, the normally mundane task of keeping my soil vibrant has become one of the few rewarding pleasures associated with soil management in organic farming. A key advantage in using compost tea is the significantly reduced application time over conventional methods of applying bulk compost. Even more important than the minimal labor requirements needed are the fact that this aerobic tea is the most alive solution you can apply to your crop. Not only have we achieved healthier plants and higher yields, our fruit tastes as good as nature intended.

Ed Leach
Umpqua Organic Farm
Roseburg, Oregon
www.asianpearsorganic.com

This past season we began several trials using compost teas produced in the Microb-Brewer. We are very pleased with both the ability of the tea to quickly improve soil biological levels and the teas ability to suppress downy mildew in our cole crop seedlings. We are confident that compost tea applications will become an important part of our field and greenhouse cultural practices.

Joel Reiten
Territorial Seed Company
Cottage Grove, Oregon
www.territorial-seed.com

Note: See the Territorial Seed Company website for a picture of the field trial where conventionally grown tomato plants were very prostrate, low to the ground, and set blossoms once during the summer. The tomato plants treated with two-applications of tea (planting day and day 45 post-planting) grew as bushes, with continuous blossom set and thus continuing tomato production. No blight was observed on the tea-treated tomato plants, while the conventional tomato plants suffered from blight.

The use of compost tea on our golf course has increased the health of our turf significantly. Disease, including dollar spot and summer patch, has decreased. Our applications of fertilizer have also been reduced, and the turf looks just as good as it did with the inorganic fertilizers. I attribute this to the dramatic increase in the health of our soil.

Charlie Clarke CGCS
Woodbury Country Club
Woodbury, NJ
wccgolf1@bellatlantic.net

I just wanted to let Dr. Ingham know that I had some great results with compost tea this year. I applied foliar spray of compost tea to my fruit trees in the spring and about two weeks after fruit had begun to mature. Anecdotally I had no coddling moth, no apple maggot, no curcurlio, no leaf curl and very little scab (apple, pear, peach, cherry, plum and Italian Prune.

Black spot on the leaves of my roses was not a problem this year and aphids were not present.

As for the vegetables we acquired a new property in June so we got started late. The area had previously been used for commercial greenhouses to grow heathers and was a compaction of rock and sand over clay that had been covered for many years with a ground cloth that allowed water to pass through. I took starts of tomatoes and cabbages and planted directly into this dreadful soil. I drenched each plant with about a quart of 1/1 compost tea. Then stood back and watched as the plants grew. The cabbage was sweet and had no slugs! The tomatoes cranked out about a quart of cherry tomatoes a day for two months. I used no fertilizer, other than the calcium and 6-6-6 organic fertilizer in my seed start mix (coir/sand/compost).

This was a very cool first attempt.

Many thanks to Dr. Ingham.

Sam Weis
Southworth, Washington

Experiences in Natural Golf-Course Practices at Bandon Dunes Resort

Presented at Golf Consultants International, 2000 in Frankfurt, Dec. 5

Speaker: Troy Russell, Superintendent at Bandon Dunes Resort, Bandon, OR, 97411, USA

ABSTRACT:

The unique location of the BDR in the dunes, right at the Pacific Ocean, and in an environmentally protected area, required a natural approach on the golf course practices. The challenge was to research what natural practices are available and carefully apply, check results and gain reproducible results and experiences. The basis of our NGCP (Natural Golf Course Practices) is founded on the properties of the most natural system. To return the system to the most natural system, materials were applied that would bring the natural system back into place most rapidly, for example, the use of compost, which contains humic acids, a wide spectrum of beneficial microorganisms and last but not least, organic matter. The other components of this system are minerals, which can be added as organic or inorganic forms. The challenge was to copy nature on an industrial scale and in a fashion, suitable for easy golf course or management. After gaining a 2-year experience, I feel confident and am happy to share those experiences with you.

Results from Compost Tea Applications

Charlie Clarke, superintendent at Woodbury Country Club, New Jersey reports 33% reduction in fertilizer applications each of hte three years he has used compost tea. In addition he reports nearly complete reduction in diseases, including eradication of dollar spot on his greens and significant reductions in water use thorugh the whole course.

George Hahn (WormGold) and *Carole Eddington* (graduate student) in California are testing a means of preventing Sudden Oak Death in conjunction with researchers at UC schools.

Randy Thomas (Nu-Vision Ag in Blackfoot, ID), *Ken Patterson* (Soil Logic, in Paul, ID) and *Carl Bailey* (Crop Care in ID) apply compost tea to tousands of acres in Idaho and Montana on potato and sugar beet. They have reduced pesticide use, reduced fertilizer use, reduced water use and reduced damage from insect feeding by applying compost tea correctly. In some cases, was used in conjunction with chemical applications. In all cases, higher potato yields, from 27 to 54 bags per acre, were recorded.

David Nobbs while at Coyote Hills Golf Course in Fullerton, California cut his fertilizer bill in half and his pesticide usage by 2/3 using a biological approach, including compost and compost tea. He is now at Uplands Hills Country Club where he expects to do the same. This year he will be monitoring water usage to see what reductions will be made.

Troubleshooting

Problem	Possible Cause	Solution
Offensive odor	Growth of anaerobic bacteria	Increase aeration
Separation of water and ingredients within tank	Insufficient mixing	Provide an adequate and reliable method of mixing
Allergic responses	Microorganisms, plant materials that cause allergies	Change recipe and/or compost source
Clogged nozzles/sprayers	Particulate matter in tea	Smaller mesh size for bag holding compost, make sure materials dissolve in water, improve cleaning
No apparent value of tea application to the plant	Compost source low in corrrect microorganisms	Inoculate compost with desired microbes. Use quality compost
Adverse reaction to tea by browning, wilting	Fungal:bacterial ratio out of balance. Tea is anaerobic	Adjust recipe to suit the crop and soil type. Increase mixing
Tea not "sticky"	Lacking organisms that attach to foliage	Add a surfactant that is also a microbial food, such as yucca, to the final spray tank mix
Variation from batch to batch	Inconsistent compost source or food resources, poor mixing, inconsistent brewing time Variability in ingredients Water source inconsistent, tea:water ratio not consistent	Monitor compost ingredients closely Check tea during brewing Use temperature increase as monitor of brewing time Have water analyzed Control dilution ratio closely
Excessive run-off from leaf	Droplet size too big	Use a finer droplet size sprayer or mist

Literature Review of Compost Tea Use

Compost teas have been shown to be beneficial in a number of cases, but to date, most testing has been rather anecdotal. Research on compost tea is in its infancy both in academic circles and in practical applications more work is needed to fully understand the effects of all the different factors.

Conventional agricultural practices are the standard against which compost tea practices should be compared. However, yield alone should not be used to compare the differences between systems. The full cost of conventional management must include the pesticides, their application costs (gasoline, machine wear, salaries and health insurance), and the cost of cleaning up drinking and ground water. Similarly, the costs of making or purchasing good compost and preparing the tea should be added to the tea system.

Compost teas can be used as crop protection tools for the control of foliar diseases and as an inoculant to restore or enhance soil microflora (ATTRA website: www.attra.org). A selection of research from Germany, Japan, Israel, and the United States has shown compost extracts to be effective in the control of the following diseases:

Disease	Compost Used	Causative Agent, Citation
Late blight of potato, tomato	Horse compost extract	*Phytophthora anfestans* Weltzein (1990)
Grey mold on beans, strawberries	Cattle compost extract	*Botrytis cineria* Weltzein (1990)
Fusarium wilt	Bark compost extract	*Fusarium oxysporum* Kai, et al. (1990)
Downy & Powdery mildew on grapes	Animal manure/straw compost extract	*Plasmopara viticola, Uncinula necator* Weltzein (1989)
Powdery mildew on cucumbers	Animal manure/straw compost extract	*Sphaerotheca fuliginea* Weltzein (1989)
Grey mold on tomato, pepper	Cattle manure/chicken manure compost extract, Grape marc compost extract	*Botrytis cineria* Elad, Shtienberg (1994)
Apple scab	Spent mushroom compost extract	*Venturia conidia* Cronin, Andrews (1996)
Late blight of tomato	Compost	*Phytophthora anfestans* Jongebloed, Kessel, Molhoek, Van der Plas (1992)
Grey mold	Compost	*Botrytis cineria* McQuilken, Whipps, Lynch (1992)
Grey mold	Fermented compost	*Botrytis cineria* Urban, Traenner (1992)
Bacterial speck	Bark compost	*Psudomonas syringae* of Arabidopsis Weizheng (1997)

(copied with permission from Steve Diver, www.attra.org, 1998, with additions by ERI)

Recent Experimental Results

SARE grant (2001). This is a recent update of on-going work from the Sustainable Studies Institute, Eugene, OR. In this experiment, we are working with three different vineyard cooperators in the Willamette Valley. One is in McMinnville, OR, the second in Wren, OR, and the third in Monroe, OR. The experimental design was application of a good compost tea to five rows of the vineyards every two weeks, application to a different set of five rows every week, compared with the control which is the rest of the vineyard using the grower s normal practices. During the summer, anaerobic teas were made and applied once. We intended to find strongly fungal materials and apply a strongly fungal tea, but the problems with extraction and compost quality have proven too difficult, and this application will be a part of the next year s study.

Three 12 gallon Micro-Brewers were donated to the Sustainable Studies Institute for use in this study. Initially the teas made were barely acceptable in terms of bacterial biomass, and were almost completely lacking in fungal component. The compost being used was changed, because initially, worm compost was mixed with some strongly fungal mushroom compost, but the mushroom compost was shown to contain many inhibitory compounds which killed the other organisms in the tea. The next compost used was a combination of strongly fungal worm compost and strongly fungal thermal compost, which as it became difficult to afford the thermal compost, strictly fungal worm compost was used. These are the joys of having budgets.

Application starting times in the spring varied in each vineyard, because of growers practices. This wasn t the experimental design, but there are times when practicality overcomes any other consideration. Because we were limited in the amount of tea being made per batch, each vineyard diluted the tea to the correct amount to cover the rows within their vineyard. At the Monroe vineyard, this meant the tea was diluted 1:5, at Wren tea was diluted 1:1 and at the McMinnville vineyard, no dilution was used, but then two rows were not sprayed, and used as an untreated control.

In mid-June, a mildew alert was released by the OSU Extension Service, indicating that mildew was in epidemic proportions and all growers should be aware that it was perfect conditions for mildew outbreaks to occur. None of the vineyards, at either application rate, reported mildew.

The last week of July, the tractor at the Monroe vineyard broke down, and no tea was applied for three weeks. During the week of August 5, 2001, mildew was found in the block that had been last sprayed the week of July 20, and had only received tea sprays every two weeks. Small levels of mildew were found in the weekly block, which had not been sprayed since the week of July 20. Clearly, maintaining protection was critical. The block with high levels of mildew was sprayed with fungicide, which ended the mildew infestation, and the block went back to normal tea applications. No further mildew spread was observed. In the weekly block, since the tractor had been fixed, tea application ended the mildew outbreak.

In the Wren vineyard, in the block sprayed every other week, mildew was found on some grapes during the week of August 5. Therefore, tea application was increased to once a week, and increased to no dilution in both blocks. Once the danger of infection was over, the tea applications returned to weekly and bi-weekly.

No mildew was observed in the McMinnville vineyard, except in the untreated control areas. Once mildew was observed, tea sprays were initiated and no further mildew was observed.

The most recent results from the trials were that grapes in the tea-treated areas were ready for harvest weeks before conventional grapes were ready to be picked. This reduction in ripening time is significant with respect to being able to iniitate wine-making operations in the late summer.

These results clearly show the importance of dose-rates, and that the level of bacteria and fungi on the leaf surfaces is critical. The ability of tea to prevent botrytis will be assessed after color-change on the grapes this summer (2001) and this study is scheduled to continue next summer as well. Further analysis of the results will be published, so that correlations with the exact leaf coverage and ability to prevent disease will be possible. As we continue to search for methods to improve fungal extraction from the compost and to improve fungal growth in tea, the strongly fungal tea may be possible and will be assessed in the future. The anaerobic tea tested the weeks of August 12 and 19 did not result in any improvement in organism coverage on leaf surfaces. During the winter of 2001, further work will be performed to enable anaerobic tea applications throughout the summer of 2002.

Experiment #1. Using a prototype of the Microb-Brewer, the Soil Microbial Biomass Service at Oregon State University used compost provided by Ron Stewart of Columbia Gorge Organic Fruit Company. A number of scientific studies have shown that increased microbial diversity and biomass improves plant growth. The classic study one the effects of improved soil diversity on plant production was performed by Ingham et al., 1985, but the entire literature is reviewed in Killham, 1994, Coleman and Crossley, 1995, Sylvia et al., 1998. In the brewer, the quantity of beneficial organisms was improved and pathogens were not found. The maximum bacterial, fungal, protozoan and nematode numbers occurred between 18 and 24 hours in the brewing cycle.

Microorganism biomass was assessed using direct methods. Both fungal and bacterial biomass were determined using fluorescent stains and UV epi-fluorescent microscopy or Differential Interference Microscopy (DIC). Diversity was assessed by morphological characteristics during direct microscopic examination and colony morphology on spread plates. Protozoan numbers and species diversity were determined from MPN plates, each well examined directly using DIC to allow identification to genus. Nematodes were identified following concentration of the tea using a 5 um mesh size screen sieve, and identification to genus by direct examination using DIC.

Grape Foliar Experiments. There are beneficial bacteria and fungi on leaf surfaces that protect plants from disease as well as produce and retain nutrients (Andrews, J.H. et al., 1991). The following data demonstrates that this protective biofilm inoculated onto a detached leaf surface by compost tea suppresses disease.

These data are exemplified in a series of slides now available from SFI s website, called the Slide show (www.soilfoodweb.com).

% of grape leaf covered by tea bacteria	% of grape leaf challenged by *Botrytis cinerea*	Visual observation of grey mold growth on leaf surface
0% (no tea, water only)	70%	Visible growth of mold occupying 1/3 of leaf surface
10% tea	70%	One spot of mold, 1/2 inch in diameter
20% tea	70%	One spot of mold, 1/2 inch in diameter
30% tea	70%	Barely noticable growth of mold, less than 1/4 inch in diameter
60% tea	70%	Barely noticable growth of mold, less than 1/4 inch in diameter
90% tea	70%	Barely noticeable mycelial strands on surface, no visible colony growth
90% tea	0%	No *Botrytis*. No visible signs of disease on leaf

Territorial Seed Experiment, Summer 2000 — During the summer of 2000, tomato seedlings were grown in the greenhouse and planted in three fields in different areas of the upper Willamette Valley near Cottage Grove, OR. Four different treatments were applied to plots in these three fields:

(1) Conventional practices,

(2) A single foliar/soil drench immediately after planting,

(3) Tomato planting tray soil soaked with tea before planting, and

Foliar/soil drench at planting, foliar tea applied every 10 days to 2 weeks.

Tea was made using the standard Bacterial Tea recipe and using buffalo compost with a strong fungal component. Results from this work will be published in a scientific journal. However, several conclusions can be drawn from these results:

- **Using Good Compost is critical** — Compost stored in a barrel and watered several days before use was tested, it was found to have become anaerobic based on active bacteria, total bacteria and protozoan analysis. The compost was tested two different times, and tea was made from that compost using an early-design Microb-Brewer. The tea produced contained very few organisms of any kind, because the compost contained few organisms of any kind. Leaf surfaces were tested for coverage by the beneficial organisms, and leaf surfaces were found to be not adequately covered —only 22 to 30% coverage. This is not adequate to exclude or inhibit disease-causing organisms from the leaf surfaces.

This demonstrates the importance of knowing that the compost contains the organisms needed, that the tea contains the organisms needed, as well as the leaves. When designing a testing scheme, it is probably most useful to test leaf organism coverage (Leaf Organism Assay). Results are returned from the lab within 24 hours, so you know whether you achieved adequate coverage or not. If coverage was not adequate, and if disease-organism spores or cells are dispersing, an immediate re-spray of better compost tea is indicated. You may also want to investigate where along the tea making process tea quality is being reduced. Is the compost good compost? Does it contain the organisms needed for the application you are using it for? This is bacteria and fungi for foliar sprays; bacteria, fungi, protozoa and nematodes for soil applications.

- **Seasonal Variation in Organism Activity on Leaves** —Through the summer, leaf coverage was monitored in the Territorial Seed Company tomato trials. Following spraying of each tea, as documented by analysis of the compost, the organisms in the tea (good biomass of bacteria, fungi, protozoa and nematodes present in the tea produced by the Microb-Brewer) and the leaf surfaces (Leaf Organism Assay), leaf surfaces were monitored immediately, 24 hours and 48 hours after spraying. Results indicated that through the summer, survival of the organisms on the leaf surfaces varied weather conditions. In cool, rainy weather, the organisms did not remain active on the leaf surfaces for more than 25 hours. During warm, dry weather, the organisms on the tomato leaves remained very active and increased in number.

More studies of organism survival on leaf surfaces needs to be performed to indicate how often tea sprays need to be performed in different weather conditions. In warm, dry weather, sprays may only need to be done once every two to three weeks. In cool, rainy weather, stickers may need to be added to the tank to improve retention on leaves. It may be a good idea to assess combinations of dormant oils and teas, to see if combinations of this kind would improve growth on leaves during wet, cool periods. Addition of yucca (a product called Saponyn from Helena Chemical Company which does not contain preservatives) to tea in other trials appeared to improve organism survival on the leaf surface, as well as increase their ability to remain on the leaf surface through rainy conditions.

Potato Trials at Oregon State University — Potato field plots were established a number of years ago at the Oregon State University Lewis Brown Farm just outside Corvallis, OR. These plots were maintained by Dr. A. Mosely, Department of Agronomy, Oregon State University. A number of treatments were within the experimental design, but to three plots within the randomized design, compost tea was the only application made to the potato plants during the summer besides routine and standard irrigation water. Compost tea, made with a Microb-Brewer, and using the standard Bacterial Tea recipe, was applied every 10 to 14 days to three plots. Controls using standard conventional practices were maintained. Wilt inoculum (Dr. M. Powelson, Oregon State University) was applied to all plots during the late summer. The results of these trials will be published in scientific journals. However, several conclusions can be drawn from the trials.

- **Tea from Different Composts versus % Disease Suppression** - The kind of compost used to make tea made a difference in level of disease-organism incidence on both leaves and tubers. The best reduction in foliar disease occurred when still-warm (100° F), moisture-maintained (54% moisture) compost was used. This compost contained highly active bacterial populations, which transferred to the tea and grew rapidly during the 20-hour tea brewing cycle. Fungal biomass, protozoa and nematode numbers were low in this tea, however. This tea was not effective at controlling tuber infection, based on no significant difference from the control tubers with 60% of tuber surfaces covered with disease-organism as assessed by visual surface inspection and confirmed by plating on PDA. However, the tea made from older, fully mature compost that was at ambient temperature, but also with good moisture levels (45%), was effective at controlling tuber disease-organisms levels (reduced to less than 3% of tubers with disease-organisms infecting their surfaces.) This mature compost tea had fewer active bacteria than the immature tea, but also contained good numbers of fungal biomass, protozoa and nematodes. This tea reduced the presence of foliar infection as well, but not quite as well as the immature compost tea.

It is important to recognize that the set of organisms in the tea can vary, and that this may influence the application for which the tea is best suited. The tea containing all the organisms would be more generally useful, but the tea with high bacterial activity was the most useful at reducing the presence of foliar disease-organisms on the leaf surfaces. Thus, for a foliar application, immature compost might be the best choice, while for a soil application, mature, more fungal dominated compost with higher numbers of protozoa and nematodes would be the better choice.

The Lawn at Soil Foodweb Inc. — The front lawn at Soil Foodweb Inc. is maintained using strictly compost tea and organic inputs. Generally, the lawn looks extremely healthy, with no disease and no weeds. However, twice the lawn care service for the rest of the property decided to fertilize the front lawn with chemical fertilizers, or apply herbicide or pesticide as a preventative measure. Addition of these chemical inputs generally reduced organisms in the soil and some effort was required to resuscitate the bacteria, fungi, protozoa and nematodes and return nutrient cycling and nutrient retention to that required to maintain the lawn. Resuscitation took several weeks to a several months, depending on the time of year. When chemicals were applied in the fall, protozoa could not be re-established in the soil until late the next spring. Whether this was a soil temperature issue, or there was residual chemical killing the protozoa is unknown.

During the summer of 2001, the folks at Soil Foodweb Inc. have been extremely busy dealing with soil samples, so analysis of the lawn has not occurred. However, regular application of tea has continued, and the lawn at SFI gets praised even from the chemical lawn folks who care for the other buildings nearby. The lack of any turf disease, weeds and the greenness of the lawn is always a source for comment.

Lawn with a single tea application (green area just above center, right) compared to conventionally maintained (and watered) lawn around it

Your Feedback

1. We invite you to tell us what does and doesn t work well. Be sure to include detailed information about:

2. The kind of compost

3. Which machine or method was used

4. Ingredients added to the tea solution

5. Brewing time

6. Time between tea completion and application of the tea

7. The application method

8. Include information about unusual temperature, moisture, etc.

9. The plant applied to

10. Check the Soil Foodweb e-zine for these feedback reports!

Glossary

Abiotic Not biotic; not related to life or specific life conditions. Usually meaning physical or chemical factors, such as temperature, humidity, inorganic chemicals.

Aerobactor A specific genus of bacteria, most of which are strictly aerobic bacteria.

Aerobe Any organism requiring atmospheric concentrations of molecular oxygen as the final acceptor in metabolism.

Anaerobe —Any organism requiring reduced oxygen concentrations, or elevated carbon dioxide concentrations in order to be able to perform metabolic processes. Strict anaerobes typically are killed by even the slightest oxygen concentrations, while facultative anaerobes can function in both aerobic and anaerobic conditions, but use very different metabolic pathways depending on oxygen concentration.

Bacillus A specific genus of bacteria, typically Gram-positive, rod-shaped, aerobic, spore-forming bacteria, often occurring in chainlike formations. Used generically, any rod-shaped, chain-forming bacterium.

Bacteria Unicellular microorganisms, occurring in many forms, existing either as free-living organisms or as parasites, with a broad range of biochemical, often pathogenic properties

Beneficial Organisms Non-pathogenic life; often improving the growth of a desired organism in a more-or-less mutualistic association where both organisms benefit from the presence of the other.

Butyric Acid A volatile organic acid produced through the incomplete anaerobic oxidation of organic matter, typically identified as sour milk smell.

Decomposition The process of conversion of organic material from one form to another, generally with biomass production by the organism doing the decomposition, production of metabolic waste products and carbon dioxide.

Disease Suppression The ability to inhibit, compete with, or consume disease-causing organisms preventing them from causing disease.

Exudates- Simple sugars, proteins, carbohydrates, hormones released by plants into the environment, typically for the express purpose of encouraging the growth of bacteria and fungi which form a biological shield around the plant, preventing disease-causing organisms from detecting the root.

Facultative Anaerobe Organisms that can perform metabolism using either oxygen or inorganic molecules as the final electron acceptor in metabolism. These organisms generally switch from aerobic to anaerobic metabolism at low oxygen concentrations.

Fermentation A specific group decomposition process that typically involves the production of carbon dioxide. Both aerobic and anaerobic processes can be included as fermentative process, although usually this term refers to anaerobic fermentation where alcohol is produced. Wine or beer fermentation, for example.

Fermentor A vessel used for fermentation processes, such as making beer, wine. Broadly applied, any container in which metabolic processes are being performed.

Fulvic Acid A particular fraction of complex humus material composed of medium molecular weight long-chain organic compounds, typically 2000 to 6000 dalton length chains. Of the recalcitrant humic materials, these can be used by bacteria. Turnover times may be 100 to 300 years in soil.

Fungi Plants of the division Thallophyta, lacking chlorophyll, ranging in form from a single cell to a body mass of branched filamentous hyphae that often produce specialized fruiting bodies and including the yeasts, molds, smuts, and mushrooms.

Foodweb The set of organism relationships, often based on who-eats-who, or which organisms cycle a particular nutrient within an ecological community.

Humic Acids A particular fraction of complex humus, composed of extremely recalcitrant, high molecular weight, very long-chain organic compounds typically 6,000 to 600,000 daltons in lengths and highly structured in a three-dimensional manner. Very resistant to decomposition, and highly condensed. Turnover time in soil may be 300 to 3000 years.

Humics The mixture of all recalcitrant, long-turnover time organic compounds in soil, includes both fulvic and humic fractions.

Metabolites Organic compounds produced by metabolic processes.

Mycorrhizal Fungi - VAM are a set of mycorrhizal fungi that form arbuscules and vesicles within the roots of plants, while ectomycorrhizal fungi form a net, called the Hartig net, within the first one-to-two cell layers of feeders roots and send rhizomorphs along the root surface. Host ranges of row crops for VAM are quite broad; the important factor to understand in choosing species of VAM is climate. When growing conifers, ectomycorrhizal fungal experts should be consulted.

Nematodes Any of various worms of the phylum Nematoda having unsegmented threadlike bodies. There are four major functional groups in soil including bacterial-feeding, fungal-feeding, predatory (eat other nematodes) and root-feeding.

Nutrient Cycling A biogeochemical cycle; the process of conversion of organic and inorganic material from one form to another, generally with the production of biomass by the organism doing the cycling, production of metabolic waste products which serve as the next step in the nutrient cycle, and carbon dioxide.

Nutrient Retention The opposite of leaching, extraction or loss of nutrients. The least mobile nutrients will nearly always be the organic forms, and the most mobile, or leachable, are the mineral forms. Retention requires nutrients to be physically immobilized by inclusion in organic matter (in organisms or organism waste-products such as bacteria, fungi, plants or plant detritus) or by chemically binding on the surface of clay, sands, silts or organic matter.

Organism A plant or animal; a system regarded as analogous to a living body.

Phenols A benzene carbon ring structure with hydroxyl groups at various positions attached to the carbons in the ring, typically resistant to enzyme attack and therefore considered relatively resistant to decomposition. Many phenols have antibiotic or toxic capabilities.

Predator — ~~An~~ organism that consumes other living organisms, as opposed to a decomposer, for example, which consumes dead plant material, a primary producer that uses sunlight for energy.

Prey—An organism that is eaten by a predator.

Protozoa A group of single-celled animals whose major prey group is bacteria. The three major groups of protozoa that occur in soil are the flagellates, the amoebae, and the ciliates. Amoebae can be separated into naked amoebae, and testate amoebae. Because bacteria contain much more N per unit C, N is released as ammonium, a plant available form of N.

Pseudomonas A genus of bacteria, some species in this genus are plant-pathogens while some are extremely beneficial to the growth of some plants. Taxonomic revision of this group of species is underway.

Soil Aggregation Soil particles (sand, silt, clay parent material) are bound together through the actions of microorganisms, and the space between these particles formed through the bonding action, and by the larger faunal organisms in soil. The more aggregated the soil, in both small and larger ped structures, determines in part how water, roots and nutrients will be held by that soil.

Soluble Capable of being dissolved in water; in solution.

Strict Anaerobe Organisms that perform metabolism using oxidized forms of nutrients (carbon dioxide, nitrate, nitrite, sulfate, sulfite, etc.) as the final electron acceptor in metabolism. Strict anaerobes will be destroyed when they come in contact with di-oxygen, or ozone, as their membrane structure is broken down by these compounds.

Valeric Acid A volatile organic acid produced through the incomplete anaerobic oxidation of organic matter, typically identified as a vomit smell.

Vortex Nozzle Used in the Microb-Brewer, the Vortex Nozzle creates a high velocity atomization of tea and air within the chamber of the nozzle.

Recent Literature and Resources

by Steve Diver (reprinted by permission)

Compost Tea Brewing Manual. 2000. By Elaine R. Ingham. Soil Foodweb, Inc., Corvallis, OR. 60 pages.
http://www.soilfoodweb.com/multimedia/compostteamanual.html

I highly recommend this manual to anybody who plans to make and use compost teas. Written by Dr. Elaine Ingham, it provides a practical summary of compost teas underpinned with a scientific understanding of applied microbiology, including: how to use compost teas; factors affecting compost tea quality; beneficial organisms; compost tea production methods; application methods; matching compost teas to plants and soils; bacterial vs, fungal dominated compost teas; compost tea recipes; microbial food resources for different micro-organism groups; and experimental results.

Organic Farming Research Foundation
Information Bulletin No. 9, Winter 2001
http://www.ofrf.org/publications/news/ib9.pdf

The Winter 2001 issue contains a special report on OFRF-funded compost tea research, pages 8-20. This is a 1,896K PDF file, so be patient waiting for it to download. Included among the items in the compost teas issue is Benefits of Compost Tea: A Review of the Research Literature. It lists 53 citations, but the full report see below contains 88 references in total. Other items include: Apparatus and Experimental Protocal for Organic Compost Teas , which describes and illustrates a homemade on-farm compost tea brewer; and Ef fectiveness of Compost Tea Extracts as Diseases Suppressants in Fresh Market Crops, which describes looked at the ef fectivness on compost teas to suppress diseases on strawberries, lettuce, leeks, and broccoli in British Columbia.

Effectiveness of Compost Extracts as Disease Suppressants in Fresh Market Crops in British Columbia
Sylvia Welke, OFRF Grant Report 99—31
http://www.ofrf.org/publications/Grant%20reports/99Spr.1of11.Welke99-31.IB9.pdf

The full OFRF report reviewed above; a 10-page PDF download.

Organic Teas from Composts and Manures
Richard Merrill, OFRF Grant Report 97—40
http://www.ofrf.org/publications/Grant%20reports/97Fall.1of5a.Merrill97-40.IB9.pdf

The full OFRF report reviewed above; a 51-page PDF download, with 88 literature references in the bibliography, Selected References for Or ganic Tea Extract Studies.

Compost Tea for Organic Farming and Gardening. By William Quarles. The IPM Practitioner. Vol. 23, No. 9 (September). p. 1—8.

The September 2001 issue of *The IPM Practitioner* the monthly journal from Bio-Integral Resource Center featured compost teas. An 8-page reprint is available for $7.50 total through:

Bio-Integral Resource Center (BIRC)
PO Box 7414
Berkeley, CA 94707
510-524-2567
510-524-1758 Fax
birc@igc.org
http://www.birc.org

Investigations into Liquid Compost Extracts (T eas) for the Control of Plant Pathogenic Fungi
By William F. Brinton and Andreas Trankner, a *BioCycle* conference paper http://www.woodsend.org/compost_tea.pdf

A 12-page PDF download, featuring the work of Dr. William Brinton of Woods End Research Laboratory in Maine.

Compost Practices for Control of Grape Powdery Mildew (*Uncinula necator*)
By Andreas Trankner and William F. Brinton, a *Biodynamic* journal reprint http://www.woodsend.org/will2.pdf

An 8-page PDF download, featuring the work of Dr. William Brinton of Woods End Research Laboratory in Maine.

Web Resources:

***BioCycle* Reprints: Compost Teas and Compost Microbiology**

Understanding Compost Tea
By Vicki Bess, *BioCycle*, October 2000 http://www.jgpress.com/BCArticles/2000/100071.html

Time for (Compost) Tea in the Northwest
By Adrienne Touart, *BioCycle*, October 2000 http://www.jgpress.com/BCArticles/2000/100074.html

Brewing Up Solutions To Pest Problems
By Lisa Wickland, Todd Murray and Joyce Jimerson,
BioCycle, March 2001
http://www.jgpress.com/BCArticles/2001/030164.html

Evaluating Microbiology of Compost
By Vicki Bess, *BioCycle*, May 1999
http://www.jgpress.com/BCArticles/1999/0599Art4.htm

Microbial Activity and Diversity of Soils and Composts
Vicki H. Bess, BBC Laboratories,Tempe, AZ
http://www.cranfordinc.com/Microbial%20Standard.htm

Using Compost To Control Plant Diseases
By Tom De Ceuster and Harry Hoitink, *BioCycle*, June 1999
http://www.jgpress.com/BCArticles/1999/0699Art5.htm

Anaerobic Bacteria and Compost Tea
By Elaine Ingham, a *BioCycle* article reprint
http://www.soilfoodweb.com/anaerobic.html

Microbial Profiles: Fine-Tuning the Soil Foodweb
By Karen Grobe, a BioCycle reprint, January 1998
http://www.soilfoodweb.com/biocycle1.html

Compost Microbiology

Compost Microbiology and the Soil Food Web
California Integrated Waste Management Board
http://www.ciwmb.ca.gov/publications/default.asp?pubid=857
http://www.ciwmb.ca.gov/publications/Organics/44200013.doc
6-page MS-Word download

Dr. Elaine Ingham: The Soil Foodweb & Compost Teas

The Soil Foodweb
By Elaine Ingham
http://www.soilfoodweb.com/thesfw.html

Soil Foodweb Information
By Elaine Ingham
http://www.soilfoodweb.com/sfwinfo.html

The Soil Foodweb Structure
By Elaine Ingham
http://www.soilfoodweb.com/sfwstructure.html

Foodweb Funtions in a Living Soil: The Benefits to Plants and Soils
By Elaine Ingham
http://www.soilfoodweb.com/foodwebfunc.html

Soil Organisms: Why are they important?
By Elaine Ingham; article reprint at *Compara.nl*
http://www.compara.nl/soil_organisms.htm

The Soil Foodweb: It s Importance in Ecosystem Health
By Dr. Elaine Ingham; article reprint at *Don t Panic eat Organic*
http://www.rain.org/~sals/ingham.html

Dr. Ingham s Monthly E-Zine
http://www.soilfoodweb.com/ezinearchives/
Note: The SFI E-Zine is a great place to keep up with Dr. Elaine Ingham s latest comments and notes on compost teas.

Anaerobic Bacteria and Compost Tea
By Elaine Ingham, a *BioCycle* article reprint
http://www.soilfoodweb.com/anaerobic.html

Brewing Compost Tea
by Elaine R. Ingham, *Kitchen Gardener* mgazine
http://www.taunton.com/finegardening/pages/g00030.asp

A Recipe for Tea: Start with a Good Compost
By Geraldine Warner, The GoodFruit Grower, March 2001
http://www.goodfruit.com/archive/Mar1-01/feature8.html
Content: Review of fungal dominated compost practices & compost teas from Elaine Inhgam

Web Resource Collections on Soil Biology

Sustainable Soil Management: Web Links to Make Your Worms Happy!
Steve Diver, ATTRA
http://ncatark.uark.edu/~steved/soil-links.html
Content: Web resource list from ATTRA

Soil Biology Information Resources For Land Managers, Resource Professionals, and Educators
http://www.statlab.iastate.edu/survey/SQI/SBinfo.htm
Content: Web resource list from NRCS-Soil Quality Institute

Compost Specialists: David Granatstein & Harry Hoitink

Suppressing Plant Diseases with Compost
By David Granatstein; *The Compost Connection for Washington Agriculture*
October 1997, No.5
http://csanr.wsu.edu/compost/newsletter/compcon5.html

Foliar Disease Control Using Compost Tea
By David Granatstein, *The Compost Connection for Western Agriculture*, January 1999, No. 8. p. 1-4.
http://csanr.wsu.edu/compost/newsletter/Cc8.PDF

Compost Teas and Liquid Humus
David Granatstein, CERWA http://www2.aste.usu.edu/compost/qanda/teas.htm

Controlling the Compost Process: Compost-Amended Potting Mixes
Ohio State University Fact Sheet, CDFS-160
H. A. J. Hoitink, M. J. Boehm, J. E. Heimlich http://ohioline.osu.edu/cd-fact/0160.html

Compost and Disease Suppression

Bibliography on Compost for Disease Suppression
Compiled by Chloe Ringer, 1998
USDA Soil Microbial Lab, Beltsville, MD
http://ncatark.uark.edu/~steved/compost-disease-biblio.html

Disease Suppressive Potting Mixes, ATTRA
http://www.attra.org/attra-pub/dspotmix.html

Sustainable Management of Soil-borne Plant Disease, ATTRA
http://www.attra.org/attra-pub/soilborne.html

Suppressing Plant Diseases with Compost
By David Granatstein; The Compost Connection for Washington Agriculture
October 1997, No.5 http://csanr.wsu.edu/compost/newsletter/compcon5.html

On-Farm Composting: Plant Disease Control / On-Farm Composting - A Review of the Literature
Alberta Agriclture, Food and Rural Development
http://www.agric.gov.ab.ca/sustain/compost/plantdisease.html

Composts for Disease Suppression
UConn Integrated Pest Management
http://www.hort.uconn.edu/ipm/general/htms/composts.htm

Microbial Ecology of Compost-Induced Disease Suppression
Eric Nelson et al; Proceedings of the 5th International PGPR Workshop
http://www.ag.auburn.edu/argentina/pdfmanuscripts/nelson.pdf

Disease Suppressive Compost as an Alternative to Methyl Bromide
Methyl Bromide Alternative Case Study, EPA 430-R-97-030
10 Case Studies, Volume 3, September 1997
http://www.epa.gov/spdpublc/mbr/compost3.html

Compost Teas: Regional Reports

Compost Tea Trials Final Report
Submitted to Office of Environmental Management, City of Seattle.
By Cascadia Consulting Group, March 8, 2001
http://www.cityofseattle.net/environment/Documents/Final%20Compst%20Tea%20report.pdf
A 53-page PDF download

Alternatives for Use & Management of Compost Tea
Clean Washington Center
http://cwc.org/organics/cm002.htm
Access to HTML and PDF versions

Evaluation and Prioritization of Compost Facility Runoff Management Methods
http://cwc.org/organics/organic_htms/cm002rpt.htm
http://cwc.org/organics/org002rpt.pdf
53-page PDF download. Report addresses the resuse of a pasteurized compost leachate from city zoo for use as a tea to fertilize crops. The liquid plant food, a compost tea product called *Zoo Broo,* will be marketed along with the zoo s other compost product, *Zoo Doo*.

Evaluation of Compost T ea for Reuse Opportunities (1997 & 1998)
Clean Washington Center
http://cwc.org/organics/cm981.htm
Access to HTML and PDF versions

Evaluation of Compost Facility Runoff for Beneficial Reuse, Phase 2
http://cwc.org/organics/organic_htms/cm981rpt.htm
http://www.cwc.org/organics/org981rpt.pdf
39-page PDF download. Phase 2 report on compost leachate reuse.

Compost Teas: Popular Press

Brewing Compost Tea
by Elaine R. Ingham,
Kitchen Gardener mgazine http://www.taunton.com/finegardening/pages/g00030.asp

Bainbridge Island: Healing the Earth
By Sue Edwards, The SUN newspaper of Bremerton, Washington, February 2000
http://www.thesunlink.com/news/2000/february/0211a10a.html

Compost Tea Allows Gardeners to Brew Greener Pastures
By Steve Hill, *University Week*, University of Washington
http://depts.washington.edu/uweek/archives/2001.03.MAR_08/article9.html

Wake Up Your Garden With Compost Tea
By Kathy LaLiberte, *The Innovative Gardener*, July 2001
http://www.vg.com/gardening/igjuly01.asp

Making Fermented Compost Tea
Natural Life Magazine #44 http://www.life.ca/nl/44/compost.html

From The Garden: Oxygen-Rich Compost Tea Can Help Ward Off Summer s Water Blues
By Ann Lovejoy, Thursday, March 15, 2001, Special to the Post-Intelligencer
http://seattlep-i.nwsource.com/nwgardens/lovejoy15x.shtml

Feed Your Foodweb: Compost Tea Strengthens Plants, Defends Against Disease
By Rachel Foster, *Eugene Weekly*
http://www.eugeneweekly.com/gardens/gardens01.html

Compost Teas: Research Reports

Response of *Alternaria sp*p. Blight and *Septoria sp*p. Leaf Spot to Biological Disease Control Agents in Tomatoes
Jeremy Barker Plotkin; OFRF on-farm research report
http://www.ofrf.org/scoar/plotkin.PDF

Compost Cures All
By James Saper, (from
Sustainable Farming Magazine, Summer 1997, Vol. 7 No. 3)
http://www.genesis.ca/whatsnew_5.html

Peach Brown Rot Study at Woodleaf Farm, Oroville, CA
Carl Rosato; OFRF on-farm research report
http://www.agroecology.org/cases/brownrot/studies.htm

North Coast Apple Scab Trials 1993/1994, Organic and Conventional Materials Comparison
Paul Vossen and Doug Gubler; reprint from *UC Plant Protection Quarterly*
http://www.sarep.ucdavis.edu/newsltr/v7n4/sa-8.htm

University Research
Midwest Biosystems, Tampico, IL
http://www.aeromasterequipment.com/research.html

Compost Tea and Blossom Brown Rot
Washington State University
http://depts.washington.edu/mulch/research/

Compost Teas: *The Worm Digest Quarterly*

A Homemade Compost Tea Brewer
By S. Zorba Frankel
http://www.wormdigest.org/articles/index.cgi?read=66

Compost Teas: Brewing a Sweet Blend
By Kelly Slocum
http://www.wormdigest.org/articles/index.cgi?read=65

Compost Teas: Complementary ATTRA Resources

Compost Teas for Plant Disease Control
The 1998 ATTRA publication
http://www.attra.org/attra-pub/comptea.html

Compost Teas: A Tool for Rhizosphere-Phyllosphere Agriculture
[One slide per page view on screen format; PPT .pdf = 4234K]
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Compost Teas: A Tool for Rhizosphere-Phyllosphere Agriculture
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Literature Cited

Brehaut, E. 1933. Cato the Censor On Farming. Columbia Univeristy Press, NY. 156 pp.

Brinton, William F. 1995. The control of plant pathogenic fungi by use of compost teas. Biodynamics. January-February. p. 12 15.

Cronin, M.J., D.S. Yohalem, R.F. Harris, and J.H. Andrews. 1996. Putative mechanism and dynamics of inhibition of the apple scab pathogen *Venturia inequalis* by compost extracts. Soil Biology & Biochemistry. Vol. 28, No. 9. p. 1241 1249.

Elad, Y., and D. Shtienberg. 1994. Effect of compost water extracts on grey mould (*Botrytis cinerea*). Crop Protection. Vol. 13, No. 2. p. 109 114.

Ingham, R.E., J.A. Trofymow, E.R. Ingham and D.C. Coleman. 1985. Interactions of bacteria, fungi and their nematode grazers: Effects on nutrient cycling and plant growth. Ecological Monographs 55:119-140.

Kai, Hideaki, Tohru Ueda, and Masahiro Sakaguchi. 1990. Antimicrobial activity of bark-compost extracts. Soil Biol. Biochem. Vol. 22, No. 7. p. 983 986.

Kuc, Joseph, and Norman E. Strobel. 1992. Induced resistance using pathogens and nonpathogens. p. 295 301. In: E.S. Tjamos, G.C. Papavizas, and R.J. Cook (ed.) Biological Control of Plant Diseases: Progress and Challenges for the Future. NATO ASI Series No. 230. Plenum Press, New York, NY.

Trankner, Andreas. 1992. Use of agricultural and municipal organic wastes to develop suppressiveness to plant pathogens. p. 35 42. In: E.C. Tjamos, G.C. Papavizas, and R.J. Cook (ed.) Biological Control of Plant Diseases: Progress and Challenges for the Future. NATO ASI Series No. 230. Plenum Press, New York, NY.

Weltzein, H.C., et al. 1986. Control of Downy Mildew, *Plasmopara viticola* (de Bary) Berlese et de Toni, on grapevine leaves through water extracts from composted organic wastes. Journal of Phytopathology. Vol. 116. p. 186 188.

Weltzein, Heinrich C. 1988. The effects of compost extracts on plant health. p. 551 552. In: Patricia Allen and Debra Van Dusen (ed.) Global Perspectives on Agroecology and Sustainable Agricultural Systems (Proceedings of the Sixth International Conference of IFOAM). Agroecology Program, University of California Santa Cruz.

Weltzein, H.C., et al. 1989. Improved plant health through application of composted organic material and compost extracts. p. 377 379. In: A. Djigma et al. (ed). Agricultural Alternatives and Nutritional Self-Sufficiency. Proceedings of the Seventh International Conference of IFOAM, Ouagadougou, Burkina Faso.

Weltzein, Heinrich C. 1989. Some effects of composted organic materials on plant health. Agriculture, Ecosystems and Environment. Vol. 27. p. 439 446.

Weltzein, H.C. 1990. The use of composted materials for leaf disease suppression in field crops. p. 115 120. In: Crop Protection in Organic and Low-Input Agriculture. BCPC Monographs No. 45, British Crop Protection Council, Farham, Surrey, England.

Weltzein, H. C. 1991. Biocontrol of foliar fungal diseases with compost extracts. p. 430 450. In: John H. Andrews and Susan S. Hirano (ed.) Microbial Ecology of Leaves. Springer-Verlag, New York, NY.