**Organism Ratios**

| Sample # | Unique ID | Total Fungal To Total Bacterial Biomass | Active to Total Fungal Biomass | Active to Total Bacterial Biomass | Active Fungal to Active Bacterial Biomass | Plant Available N Supply from Predators (lbs/acre) | Root-Feeding Nematode Presence |
|---|---|---|---|---|---|---|---|
| 363 | NW Vermi | 1.23 | 0.01 | 0.05 | 0.24 | 300+, but N loss | None detected |
| 364 | KIS-Thermal | 2.72 | 0.01 | 0.21 | 0.07 | 300+, but N loss | None detected |
| | | Fungal dominated compost, suitable for variety of plant applications. | Fungal component is mature. | NW vermi/ bacterial component is mature. Kis thermal Not mature. Wait to apply this material until activity drops below 10%. Material is currently suitable for making tea. | Compost will become more bacterial with time. | Excellent nutrient cycling. N loss results from anaerobic conditions, as indicated by high ciliate numbers. | Possible switchers present. Need beneficial fungi and nematodes to combat these pest conditions. |
| Desired Range | | *(1) | *(2) | *(2) | *(3) | *(4) | *(5) |

(1) For the following plants, Grass:0.5-1.5; Berries, Shrubs, grape: 2-5; Deciduous Trees: 5-10; Conifer: 10-100.
(2) Active organisms in mature compost should be below 0.10. Compost is not mature, i.e., not stable, if greater than 0.10.
(3) For annuals, ratio should be 1 or less, for perennials, ratio should be 2 or greater.
(4) Based on release of N from protozoan and nematode consumption of bacteria and fungi. Often protozoa and nematodes compete for food resources. When one is high, the other may be low. Also, if predator numbers are high, the prey may have low numbers
(5) Identification to genus.

**Nematodes per Gram of Compost**

| | 363 | 364 |
|---|---|---|
| **Bacterial Feeders** | | |
| Butlerius | 4.86 | 1.04 |
| Cuticularia | 7.42 | 14.62 |
| Eucephalobus | | 0.35 |
| Mononchoides | 0.77 | |
| Plectus | | 1.04 |
| Rhabditidae | 1.53 | 1.04 |
| Rhabdolaimus | | 0.35 |
| **Fungal Feeders** | | |
| Aporcelaimus | | 0.35 |
| Mesodorylaimus | | 0.35 |
| **Fungal/Root Feeders** | | |
| Aphelenchus | 0.26 | |
| Ditylenchus | 0.26 | 0.70 |

Chapter 14

# Tools for Restoration and Maintenance

Now that you have an idea of what populates your soils, it is time to take whatever action is necessary to ensure your soil food webs give your plants what they need in the way of nutrients and protection.

## Compost, mulch, and compost tea

This is when you begin teaming with microbes and become a soil food web gardener. With most soils, your first aim will be to restore a diverse and whole soil food web. As beneficial organisms return, you will see a difference not only in your soils but in your plants as well. Some areas (lawns and beds of annuals, for example) respond very quickly; other spots will have soil food webs that take longer to establish or alter. Much of your yard's response will have to do with previous practices. If in the past you saturated your yard with commercial pesticides, herbicides, fungicides, or salt-based chemical fertilizers, you may have to completely reestablish soil food webs; this may take a year or more. Gardeners who have been "organic" usually need only to tweak their established food webs, employing some new practices and intensifying others.

It's simple. Compost, mulch, and compost tea are the soil food web gardener's tools, and it takes only three strategies to restore the soil food web using them: applying the proper kind of compost; mulching the right way, with the right kinds of organic matter; and applying actively aerated compost teas (AACTs). Once established, soil food webs can be maintained with the same strategies, either alone or in combination. Employed properly, these management tools will replace conventional fertilizing with chemicals. These tools feed the microbes that feed the plants. If you keep the microbes happy, healthy, and diverse, you will have excellent results.

Compost has been used to support soil food web organisms long before anyone knew they existed. It is a proven, effective growing medium. Compost can inoculate an area with microbes to support a soil food web. Properly made compost contains the entire complement of soil food web microorganisms: fungi and bacteria, protozoa and nematodes. It is also full of organic matter,

which provides living space and nutrients for the gang of microbes a compost pile contains. Finished compost never smells bad, which would be a sure sign of anaerobic microbes doing their thing. It should smell earthy and fresh, and it always has a rich, dark, coffee color. The only caveat is that in modern times, one has to know what was used to make the compost, as many of the chemicals we seek to avoid do not break down quickly enough in compost.

Organic mulches, too, are an effective soil food web gardening tool. By organic we mean natural material, full of carbon and nitrogen—namely, leaves, grass clippings, and wood chips. These provide the proper environment for the soil community's organisms and plenty of organic foods for them to live on. After all, these are what make up the compost pile. Mulch is a form of cold compost: it doesn't heat up like a compost pile, but it will decay, over a longer period of time. By providing different kinds of organic matter as mulch, you can establish or supplement different members of the soil food web, ones that will provide more of the type of nitrogen preferred by the plants grown in the area.

Actively aerated compost tea is a liquid easily extracted from compost. A properly made AACT contains the same set of microorganisms as the compost from which it derives. The term "actively aerated compost tea" is used to distinguish these modern compost teas from old-fashioned teas like the ones your parents and grandparents may have made by soaking a bag of compost or manure in water for a few weeks. AACTs are prepared by pumping air into a mixture of compost, dechlorinated water, and microbial nutrients. Unlike old-fashioned teas, which went anaerobic, AACTs remain aerobic—and the aerobic microorganisms are the beneficial ones. The energy from the air bubbling through the mixture strips the microbes out of the compost and into the tea. Here they grow and multiply, forming a stew of beneficial food web microbes that can be applied to soil.

Aerated compost teas are easier to make and much easier to apply than compost and have a higher concentration of microbes, so you don't need nearly as much tea as you would regular compost to inoculate an area. These teas can also be sprayed on leaf surfaces, where compost will not stick. Here the beneficial microbes in the tea outcompete pathogens for food and space.

## More work now, much less later

Using compost, mulch, and compost tea properly will greatly reduce the amount of work it takes to maintain your yard and gardens. There is a bit of work involved in making the conversion from chemicals to microbes, but ultimately, once you gear up and make the necessary changes, there will be less to

do. The microbes will be working for you. You will need to water less because the food web animals will have improved your soil's water- and air-holding capacity. You won't need to fertilize because there will be proper microbial cycling of nutrients in the soil. And you will be able to ensure your plants are getting the kind of nitrogen they prefer.

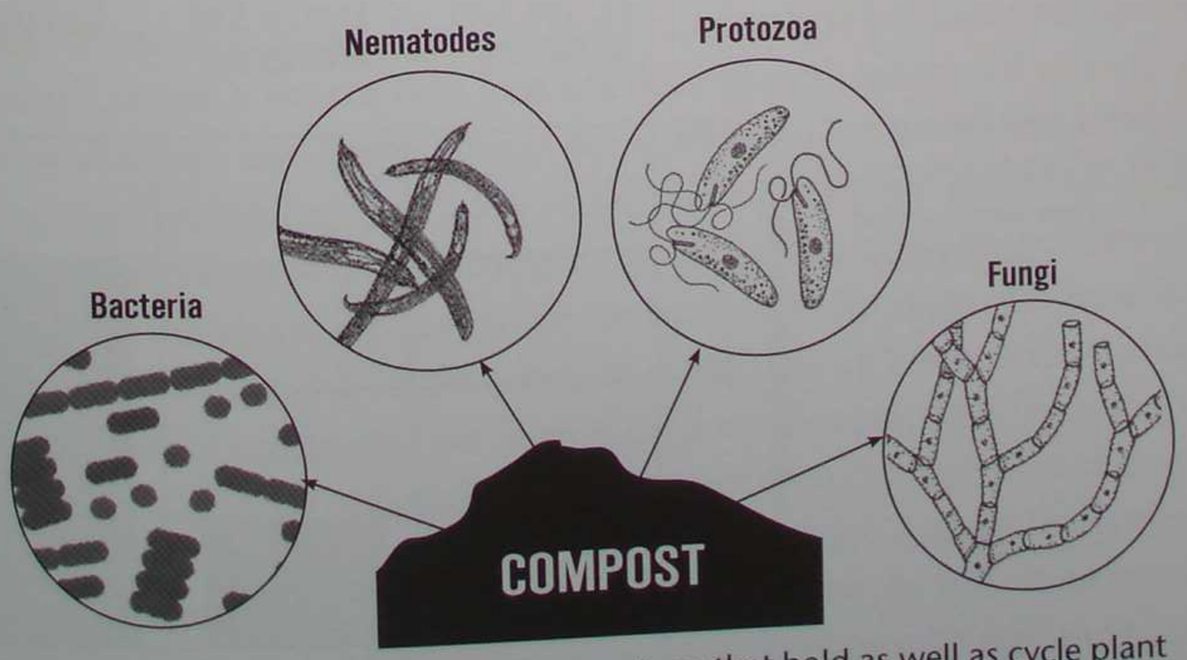
You will have fewer plant health problems and some effective, easy-to-use tools to make things better if things do go wrong. And if all this doesn't save you time and effort, not having to rototill or turn your garden soils—ever again—surely will. Best of all, there are no dangerous chemicals; nothing leaches into the water table. When you team with microbes, there is no small print to read—and no health problems for you, your family, or your pets.

You have now heard, briefly, what the main soil food web tools are; each deserves and will get its own chapter. Once you start applying all the rules using these three tools, we are quite sure there will be no looking back.

# Chapter 15
# Compost

Compost is a whole universe of diverse soil food web organisms. Never mind the huge numbers in good, fertile garden soil: the numbers of organisms per teaspoon in compost, especially the microbial populations, are simply too large to fully comprehend: up to a billion bacteria, 400 to 900 feet (150 to 300 meters) of fungal hyphae, 10,000 to 50,000 protozoa, and 30 to 300 nematodes. In addition to extremely high microbial numbers, compost contains all manner of microarthropods and sometimes worms. It teems with life.

Rule #4 (compost can be used to inoculate beneficial microbes and life into soils around your yard and introduce, maintain, or alter the soil food web in a particular area) establishes the use of compost as a major soil food web tool. Rule #5 elaborates on this: adding compost and its soil food web to the surface of the soil will inoculate the soil with the same soil food web. The organisms in the compost you apply to your gardens, trees, shrubs, and perennials will spread life as far as they can. It is microbial manifest destiny. But you can best satisfy a plant's nutrient needs by adding compost with the right microbial domination.



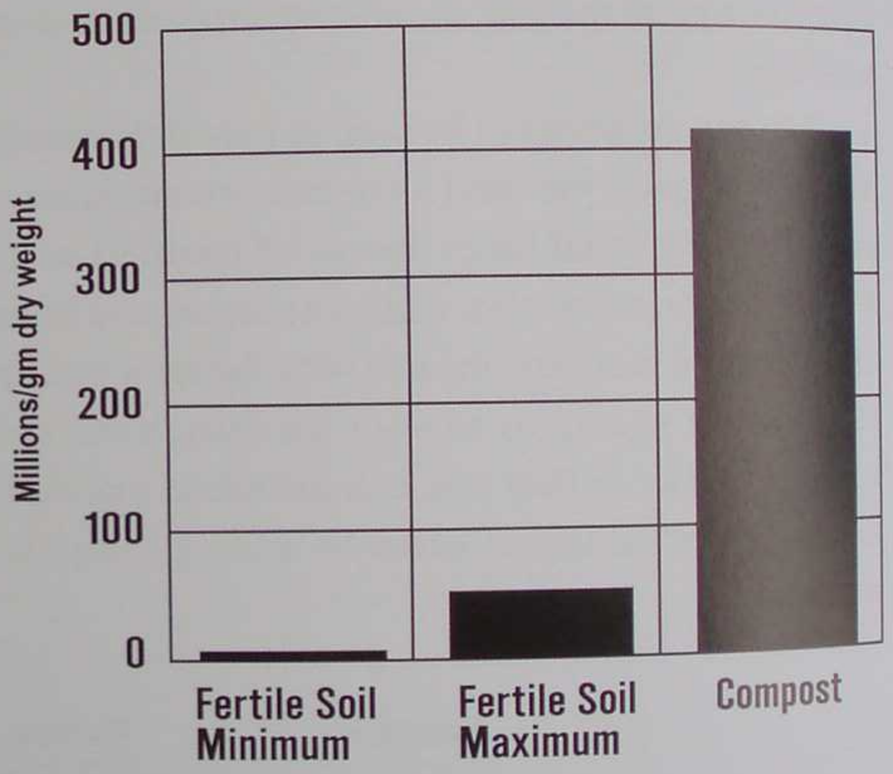

Compost contains the key soil food web organisms that hold as well as cycle plant nutrients. Courtesy Tom Hoffman Graphic Design.

## Not all composts are the same

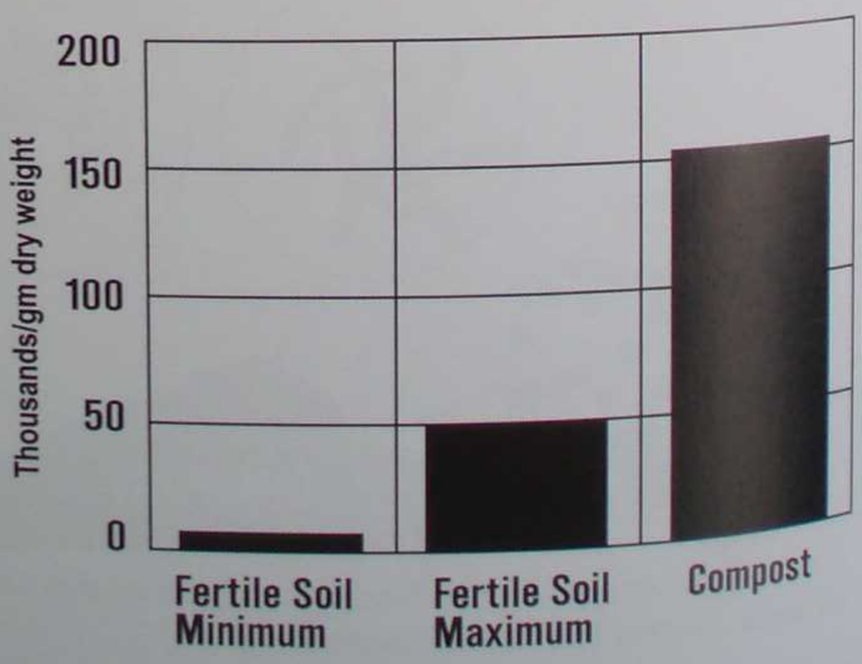
Most gardeners don't give compost much thought. They make or buy it, and they apply it—it is all the same. There is more than one kind of compost, however, which is something that amazes many veteran compost makers. We, too, thought that all compost, no matter what went into it, had the same biology and pH in the end. But surely, upon reflection—and especially after you know something about the soil food web organisms that make up compost—the idea that the end product is always the same doesn't make any sense. As with almost every other system, what goes into it does have something to do with what comes out at the end.

The fact of the matter is that by using just a bit of soil food web science, you can make either compost that is dominated by fungi or compost that is domi-

Bacteria populations in fertile soil and compost. Courtesy Tom Hoffman Graphic Design.




Fungi populations in fertile soil and compost. Courtesy Tom Hoffman Graphic Design.



nated by bacteria. It all depends on what you put into the compost pile or bin to start. And because some plants prefer their nitrogen in ammonium form and some in nitrate form (see Rules 2 and 3), making compost that fosters the production of one of these forms of nitrogen over the other makes real sense.

## How to make compost

Farmers have been using compost to improve their soils at least since the time of the early Romans. It was only in the last century that compost took a backseat to chemicals when it came to growing things; before that, if you worked on a farm or in a garden, you routinely used compost and manure to increase fertility. This all changed when internal combustion engines replaced the horse, and fewer and fewer homes, particularly in urban settings, featured chickens, cows, pigs, and other livestock. Agriculture and horticulture required chemicals because there was a dearth of manures and thus compost.

Making and using compost has made a strong comeback among home gardeners and has even become politically correct: composting conserves valuable landfill space by recycling at least some of our household wastes. Dozens of compost bins are commercially available, and a like number of books can tell you how to make compost, in myriad ways. At the heart of every composting system, however, are the soil microorganisms, the members of the compost's food web. They are the ones that make compost, no matter what method is employed. Their metabolic activity creates the heat and by-products that make the composting process work.

This is a chapter, not a book, on composting. What we will describe here is just a bit of the science behind composting and a few basic procedures for making compost at home. Once you have made a few batches, you can experiment and create a system that best fits your plants' needs and your climate, space availability, and even spousal demands. Besides the necessary soil microbes, composting requires heat, water, air, and organic materials with the right amounts of carbon and nitrogen. All are mixed in the proper ratio.

Organic materials are easy to come by: grass clippings, autumn leaves, wood chips, straw, sawdust, branches, and virtually all kitchen scraps (except meats and fats). Human and pet feces should not be composted because of the possibility that disease organisms might survive even the high heat of the compost process; for the same reason, we personally discourage the timeworn practice of using other manures in compost. Why take the risk when you don't know what kind of antibiotics and other drugs were used to feed the animals? Who wants to be worried about *E. coli*?

Bacteria, fungi, and other microbes seek mostly carbon from the organic matter in the compost pile, just as they do in the soil. This fuels their metabolism. The microbes also need nitrogen to make the enzymes used in the decay process and the proteins (including their chief component, amino acids) that are necessary to build structure and enzymes.

Moisture is necessary to provide the optimum environment for the microbes and to prevent them from dying or going into dormancy. You cannot have active bacteria, protozoa, or nematodes without the water necessary for their transport and other life functions.

Air is needed because the beneficial soil organisms that break down carboniferous and nitrogenous materials are aerobic. They breathe air; they require oxygen. It is true that anaerobic conditions can develop in a compost pile and decay will occur under these conditions as well; however, so will the production of things detrimental to plants, such as alcohols, of which as little as one part per million will kill plant cells. Obviously, then, it is important to keep compost piles aerobic, which is why compost piles are turned and opened up, bringing air into the system.

Finally, the heat required for composting does not come from the sun but rather from the soil life's metabolic activity, most of it from bacterial activity. As you will see, this heat is what creates an environment that increases populations and causes them to change in character at the appropriate time during the composting cycle.

Mix these ingredients in the right proportions, and you will end up with a rich, crumbly, dark, coffee-colored, sweet-smelling humus-soil that also happens to be full of life. Though it could take as long as a year or more, it is possible to make good compost in as little as a few weeks. But no matter what method is employed, it is the microbes that do most of the work.

## Mesophilic and thermophilic stages

Composting material goes through three distinct temperature phases. The first of these phases is the mesophilic. Mesophilic organisms thrive in moderate temperatures, between 68 and 104F (20 and 40C).

Even in this first stage, work begins on the straight, difficult-to-digest chains of cellulose, which are broken into smaller chains of glucose; bacteria are particularly adept at depolymerization, as this process is known. Meanwhile, brown rot fungi (basidiomycetes, "regular" mushrooms) and certain bacteria (*Bacillus* spp., *Heliospirillum* spp.) are active breaking down other difficult-to-digest material. These microbes produce endospores, spores that are

resistant to chemicals and heat; this enables them to survive the next, hotter phase of composting, and they return when temperatures cool.

Larger soil organisms join the fungi and bacteria, breaking apart organic matter in the pile as they search for food, and microbial activity in the guts of some of these animals results in further chemical breakdown. All this metabolic activity creates heat, raising the temperature to 104F (40C). At this point, it becomes too hot for the continued activity of the mesophilic organisms, and those adapted to higher temperatures take over.

In case you are wondering how a compost pile heats up in the spring after a frozen winter, it is simple: some bacteria are psychrophilic, meaning they thrive at temperatures just above freezing though some of them—the really "cool" bacteria—can continue to operate at temperatures as low as 32F (0C). The metabolic activity of these cool-loving bacteria increases the temperature of the pile just enough to wake up the higher-temperature, mesophilic organisms so they can take over.

Organisms in the second stage of the composting cycle, the thermophilic phase, can withstand temperatures of 104 to 150F (40 to 65C) and over. During this period the complex carbohydrates are fully broken down. Some proteins are also decomposed. Hemicelluloses, more resistant structures, are decayed. Many more bacteria (*Arthrobacter* spp., *Pseudomonas* spp., *Streptomyces* and other actinomycetes) and fungi join in or begin to play more prominent roles. Their metabolic heat causes the temperature in the compost pile to continue to rise; these high temperatures also kill off pathogens that might be in the mix.

These first two stages take place very rapidly. A properly made compost pile should heat up to 135F (57C) in 24 to 72 hours; typically, if you have the right mix of carbon to nitrogen, the center of a pile will heat up to 135F (57C) in a day and 150F (65C) in three. If the pile is not heating up, then you need to turn it (that is, switch the inside and bottom materials in the pile with the outside and top materials) to add oxygen. If that doesn't work, add fresh, green material (as these are full of easy-to-digest sugars that will supply bacteria the food they need). Newspaper, fruit pulps, or commercial compost inoculums can also be added to help a pile heat up.

You have to monitor compost piles. It is advisable to keep a pile between 140F (60C) and 150F (65C) for at least a few days because at this thermophilic temperature, pathogenic microbes in the compost are killed. At 150F (65C), weed seeds are also destroyed. Never let a compost pile get over 155F (68C) as this will start to burn off carbon. To temporarily cool an overheated pile, turn it (yes, turning encourages both heating and cooling). Not only does this open

Turning a home compost pile. Photograph by Judith Hoersting.

the pile up to air, it ensures all the material in the pile gets treated. If turning doesn't do the cooling trick, add water or more brown materials, changing the ratio of green (easy-to-digest bacterial foods) to more fungal foods. Since bacteria are the primary heat-generating organisms, this will slow things.

There is nothing wrong with sticking your hand into the pile to gauge the heat. Or you can stick a long, gutter nail or metal rebar pipe into the pile; these transmit heat and will feel warm when things are going right. A thermometer is more precise, however; you can buy a soil thermometer designed for the purpose or use an oven thermometer.

## Maturation stage

As the complex proteins and carbohydrates are broken down and begin to diminish, there is a reduction of metabolic activity and the temperature in the pile starts to decrease. The mesophilic organisms, whose specially protected spores enabled them to survive the higher heat stage, reassert themselves and replace the thermophilic organisms. The compost enters the final, maturation stage.

During the maturation stage, the decay of the most resistant plant component, lignin, is completed. The bonds holding the chains of alcohols in lignin together are extremely strong and structurally much more difficult to attack

and break apart than almost anything else in the pile. The actinomycetes, the chain-like bacteria that resemble fungi, continue their attack on these really difficult-to-digest plant remnants; these are the same organisms that impart the earthy smell associated with good compost and soil, which comes from their decay of cellulose, lignin, chitin, and protein. The major fungal participants in this last stage, the basidiomycetes, are still at work.

Also during this maturation stage, physical decomposers continue to support the microbial team. Grazing by nematodes, springtails, centipedes, and others cause the populations of fungi and bacteria to increase; and as these microbial populations increase, so do their soil-binding activities. Lots of nematodes were killed by the heat of the thermophilic stage, but those that survive have lots and lots of bacteria and fungi to eat; as a group, they do well. Worms, too, work the organic matter in the pile, exposing it to bacteria and then coating particles with a mucus that binds them together into aggregates. Ants, snails, slugs, mites, spiders, rove beetles, and sow bugs can come into the pile and open up the organic matter as they forage, shredding it and making it easier for microbes to attack. The end result of all these organisms going about their day-to-day business is compost.

It is best to keep the compost pile between 104 and 131F (40 and 55C) after the initial thermophilic run-up to 150F (65C). Make sure that the outside of the pile gets turned into the center so all the material decays. If the pile drops below 104F (40C) before it is mature, consider adding some more green, high-in-nitrogen material. If it stays above 131F (55C), consider adding more brown, carbon-containing material. Of course, aerating a pile will always initially cool it down, and if you have the strength, repeated turning is the only control you need. Watering a pile down will also cool it, but this is a more drastic step.

The pile needs to remain moist throughout the process. Don't let it dry out, but don't let it become so saturated that there is no air supply in the pile. You may have to add water as you turn the pile, or cover it to keep rain from soaking it. If all goes well, and it usually does, "compost happens." After two or three turns, your pile should be compost. It is finished, or mature, when you cannot recognize what's in it.

## C:N ratio and fungal vs. bacterial dominance

The ratio of carbon to nitrogen has to be right in order to make compost; the ideal C:N ratio for this purpose is somewhere around 25:1 to 30:1. If you have too much carbon, nitrogen is quickly used up and the decay process slows. If you have too much nitrogen, organisms snatch it up and then carbon is vented

to the atmosphere or mixed with water and washed out of the pile. But at the ideal ratio, things go fast, and decay is complete.

Often gardeners divide available composting materials into two categories, brown and green. Aged, brown organic materials support fungi, while fresh, green organic materials support bacteria (Rule #6). Brown items—including autumn leaves, bark, wood chips, twigs, and branches—contain carbon; carbon provides members of the soil food web with energy for metabolism. Green items—such things as grass clippings, fresh-picked weeds, kitchen scraps—contain plenty of the easier-to-digest bacterial foods and are good nitrogen sources. The fresher the green item, the more nitrogen it will contribute to the pile. Nitrogen provides soil food web organisms with building blocks for proteins, which are used, among other things, to produce the digestive enzymes necessary in the decay process.

Not all organic wastes at hand have the ideal C:N ratio; sawdust, for example, is 500:1, and paper is 170:1. The two organic wastes you should have a good supply of are grass clippings (19:1) and tree leaves (40:1 to 80:1)—mixed together, these will give you near the proper ratio.

It is possible to manipulate compost materials so that the end product is highly fungal or highly bacterial, or a balance of the two: simply increase brown materials (to increase the amount of fungi) or green materials (to increase bacterial counts). A good mix of materials for a fungal recipe is 5 to 10% alfalfa meal, 45 to 50% fresh grass clippings, and 40 to 50% brown leaves or small wood chips. A suitable bacterial recipe would include 25% alfalfa meal, 50% green grass clippings, and 25% brown leaves or bark.

Again, the green materials that go into compost provide simple, easy-to-use sugars and lots of nitrogen and are great for supporting bacteria. The brown materials in compost piles consist of difficult-to-digest lignin, cellulose, and tannin (and some nitrogen as well). Fungi prefer this kind of material and have the enzymes to break it down. Only then can bacteria attack it.

## Other important factors

The bacteria in compost will tend to buffer pH around 7 to 7.5. Fungi in compost will tend to buffer the pH around 5.5 to 7, so you want some fungi in all your composts to prevent them from getting too alkaline. The more fungal material in your compost, the lower the pH, to a point.

Inorganic fertilizers, pesticides, herbicides, miticides, and fungicides kill off soil food web members and therefore have no role in composting. Materials that go into compost piles should be free of these chemicals. Chances are they

will break down over time, but maybe not before the compost is spread; and why take risks with chemicals when you don't have to? In addition, since many of these chemicals are nonselective when it comes to microbes, they can interfere with the composting process itself by eliminating microbes that contribute to the heat and decay.

The size of the material put into a compost pile is also important. Too much fine, particulate matter, and the pile will compress and quickly go anaerobic. If the material is too big, there will be so much air diffusing through it that the pile will heat up too much. If the material is too large, it won't decompose properly or fast enough because the bacteria can't get into it quick enough to establish sufficient populations. There is a fine balance when it comes to size of materials put into a compost pile, and only experimentation will give you the understanding you need and, finally, the control you want.

Next, a compost pile requires a minimum amount of mass, approximately 3.5 feet square or round (1 cubic meter), in order for it to heat properly. You can make your piles bigger, but the increase in size creates more work, as the entire pile has to be aerated or turned at least a few times to keep it from going anaerobic. In our experience, a six-foot pile, wide and tall, is about as big as you will want without a lot of mechanical help turning and aerating it.

It is quite easy to make compost literally in a pile, dumping ingredients

A professional turns his compost to aerate it. Photograph by Ken Hammond, USDA-ARS.

right on the ground and mixing them. Some prefer a caged area to contain the material and to make turning easier. A single ring of fencing or chicken wire, three feet in diameter and four or five feet high works great. Using a wooden pallet or screen supported on concrete blocks at the bottom of the pile will allow air to circulate into the pile, making it much less work to maintain. Some composters swear by revolving bins for making compost: in go the organic materials and to aerate all you do is spin the drum a few times. Once you figure out how to keep the materials in the bin from getting too moist (a chronic problem with enclosed systems), these can be very effective. Again, you will need to experiment to suit your tastes and needs.

Whatever your setup, you will need to keep an eye on the pile's moisture. Place materials in layers of 4 to 6 inches (10 to 15 centimeters), alternating between green and brown, and make sure each is moist. Once metabolic activity has started, you will need to make sure that the pile stays moist for the entire composting process. Since you don't want the pile to be wet (this encourages anaerobic activity), make sure to mix wet material with dry material if necessary. If you are composting in a dry climate, flatten out or make a concave impression in the top of your pile to collect what rain does fall. Similarly, if you are composting where it rains a lot, cover the pile with a tarp or consider making compost in an enclosed bin.

If a pile is too moist, it won't heat properly. You should be able to take a handful from your pile and squeeze just a few drops of water from it, but no more. If your pile does get too wet, then add dry materials or turn the pile. This is hard work, so it is better to get it right in the beginning.

Hot composting will kill weed seeds and pathogens in most cases, but there is no reason to risk adding diseased material or really noxious weed plant material to your pile until you get the hang of the process and can distinguish compost from what we can tell is merely "almost compost." There is a big difference. You have to finish the composting process to ensure that pathogens and weed seeds have been destroyed.

How do you know you have good compost? Test it. You can send compost out to a biological testing lab, but an easier and cheaper home test is to smell the finished product. If it smells bad, like vomit or putrefying matter or vinegar, then it contains anaerobic organisms and their by-products and should not be used. If it smells like ammonia, then it is not finished. In either case, aerate it to change these conditions, and let it sit for a few days before you give it another nose test. You know what fresh soil should smell like; good compost should smell "clean" as well.

You can also plant something in it. Good compost supports plant growth. If

there are not enough predators eating the fungi and bacteria, then the nutrients they hold won't be cycled and you will be able to tell by the plant deficiencies.

## Compost for the lazy

A modern mix for "instant compost" requires three cubic yards of brown tree leaves and a 50-pound bag of alfalfa meal from an animal feed store. This mix works even better if the leaves are shredded so the bacterial microbes can get right to work decaying it. If you don't have access to alfalfa meal, start with equal volumes of grass clippings and leaves and work from there. If this pile heats up too much, use less grass. If it doesn't heat up enough, use more grass. This assumes moisture and air are adequate. We learned from experience that if you spread fresh grass clippings out and let them dry for a day or two before adding them to the compost pile, they won't mat or smell.

Make your pile in layers starting with 4 inches (10 centimeters) of leaves followed by a layer of the alfalfa meal (or grass) of the same thickness, another layer of leaves, and another layer of meal, and so forth. Water each layer lightly and then add the next. Add sticks and branches as you go along to increase air circulation through and to the middle of the pile.

Once you have accumulated at least the three cubic yards of organic material needed by your army of microbes and other soil food web organisms, they will go to work. Heat will be noticeable in 24 hours. Thereafter you will need to monitor the temperature: it shouldn't get over 150F (65C) or cool down much below 104F (40C). Turning the pile will increase the heat until the pile reaches the mature stage, after which it won't heat up when you turn it. Turning lowers temperatures temporarily until the microbes start working in concert again. Again, water will cool down a pile.

If this sounds like too much work for you, try cool or cold composting: simply pile organic matter in a corner of the yard and leave it. This material will eventually decay, only very slowly; cool composting can take a year or more versus a few weeks or months for hot composting. The end result is compost, however, and as long as it contains the proper set of organisms, it doesn't matter which system you use. Note that worms, beetles, millipedes, and other micro- and macroarthropods will be represented in higher populations in cool compost. It is, therefore, a good idea to keep a cool compost pile going at all times, no matter how energetic you are; the diversity of soil organisms it adds can only help your garden. In the soil food web, higher member diversity means a better ability to eliminate pathogens or control them, either by direct attack or by competition for nutrients and space.

## Vermicompost

Processing organic materials through earthworms makes vermicompost, which is almost always bacterially dominated (few if any fungi are involved in worm digestion). Heat is not involved, as this would kill the worms. Instead, the worms (that is, the bacteria inside them) digest the materials and create castings. You can buy special earthworms for this job and buy or make a small bin to keep them in; this can be a simple wooden or plastic box. Just out of the bin, vermicompost has a bacterial dominance; the castings—coated with a polysaccharide as well as carbohydrates and simple proteins—are perfect for supporting good bacterial populations.

Good starting materials for vermicompost include food wastes (no fats or meats), paper, cardboard, leaves, and green grass; or you can use the same materials as you would to start a normal compost pile. If your material contains weeds, thermally compost them first before adding them to the bin; this prevents unwanted seedlings from growing in the worm bin. Any brown materials need to be shredded or otherwise broken up, so the worms can ingest it quicker. With luck, your materials will also include some microarthropods to help physically break down the matter for the worms. Putting your bin outdoors will encourage arthropod and insect activity in it.

## Inoculate your soils

It doesn't take much compost to impart life to the soils. To inoculate your soils, put ¼ to 1 inch (0.5 to 2.5 centimeters) of the appropriate compost (fungal, bacterial, or balanced) around your plants. Fungal compost should be applied around trees and shrubs and most perennials; bacterial compost is most appreciated in veggie and flower gardens and lawns (review Soil Food Web Gardening Rules 1 through 4!). Compost can work its magic in the soil in as little as six months. After only that short period of time, new soil life will be evident in the first 6 to 15 inches (15 to 38 centimeters) of the soil inoculated. With this new life comes all the benefits of the soil food web: decompaction, aeration, better water retention and drainage, and increased retention and availability of nutrients. After a year, the soil life will be down as deep as approximately 18 inches (46 centimeters).

Gathering the materials and making a compost pile does take a certain amount of work. The benefits derived from compost, however, are almost incalculable when it comes to managing the soil food webs in your life. Compost is an indispensable soil food web gardening tool.

# Chapter 16
# Mulch

Mulch is anything that can be placed on top of the soil to reduce evaporation, prevent weed growth, and insulate plants. Using this definition, plastic sheeting makes great mulch. For our purposes, however, we are only interested in organic mulches, mulches that come from things that were once alive and can be recycled back into nutrients by soil food web organisms. Organic mulches include leaves and leaf mold, aged pine needles, grass clippings, aged bark and wood chips, straw, well-rotted manure (if you must), seaweed, "almost compost," plant remnants, and paper.

## New reasons to use mulches

Most gardeners are familiar with the standard reasons to use mulch in the garden. A thick enough layer will smother existing weeds by depriving them of needed sunlight or prevent them from germinating in the first place. Mulches also help give landscaped areas a neater appearance and keep soils cool when there is too much heat; where it gets cold, mulches insulate the soil, and where there are freeze-thaw cycles, mulch is great at preventing premature plant growth by keeping soil frozen. Mulches prevent the soil compaction caused by heavy rains. They greatly reduce evaporation from the soil.

Absent from the usual list of reasons to use mulch is that mulch provides nutrients and a home for certain soil food web organisms, and a good mulch works wonders in imparting soil food web benefits to the soil. For example, worms pull mulch material into underground dens for shredding; the results are nutrient-rich worm castings, more worms, worm tunnels and dens, better water retention, and improved aeration. All manner of micro- and macro-arthropods are able to live in mulches, speeding decay, adding to the soil's organic content, and attracting other members of the soil food web.

We readily acknowledge that mulch is not as effective as compost for adding microbes quickly to the soil food web. Mulch cannot match compost's diversity of soil food web organisms; the decay process has not been completed

(and may not even have started), and thus organic mulches lack the variety and numbers of compost's organisms.

We also admit that mulches can result in a feeding frenzy by bacteria and fungi which—if not matched by a feeding frenzy of nematodes and protozoa upon the bacteria and fungi—can result in nutrients being tied up to the detriment of plants in the area. This is another reason mulches control weeds so well: the biology in mulches ties up nitrogen, sulfur, phosphate, and other nutrients on the soil's surface, where the mulch is put down. These are not available to shallow-rooted weeds, while deeper down in the soil, where your plants roots are located, things are fine. When mulches are used properly, however, nutrients can be cycled from them.

The one benefit of using mulches that should be evident to you by now: if you use the right kind of mulch, you can establish dominance of fungi or bacteria.

## Bacterial vs. fungal mulch

Rule #6 remains operative here. A mulch of aged, brown organic materials supports fungi; a mulch of fresh, green organic materials supports bacteria. Mulching your garden with brown leaves will encourage a flush of fungi; placing green mulch on soil will foster populations of bacteria. Either will eventually attract microarthropods, arthropods, worms, and other soil food web participants. These will work through the mulch, pulling bits of it into the soil, shredding and tunneling through it, taxiing other members of the web to new locations. You know the routine—a soil food web evolves.

A number of good organic mulches are available free or at low cost. Fresh grass clippings, the most readily available green mulch, contain all the necessary sugars to attract and feed bacteria. Avoid grass taken from lawns where weed killers and pesticides have been applied (and don't accept clippings from yards where dogs are part of the soil food web). Be careful not to pile grass clippings too thick, as they can start to compost and go anaerobic. This will create an offensive odor or heat that can interfere with the very soil food web you are trying to impact.

Our favorite brown mulches are made from the leaves we save each autumn after they fall. These support fungal dominance unless ground up into very fine pieces (in which case they are open to bacteria, who beat fungi into the material). It is also our experience that leaf mulches grow more fungi (or at least grow fungi faster) than do wood chips.

Peat moss is often used as brown mulch. Peat, however, is biologically sterile and should be mixed with other materials to introduce some microbiology.

Pine needles, another brown mulch available to some, make great mulch, but only after they are aged a bit: they contain terpenes, volatile chemicals that are toxic to many plants. Cedar chips also contain high levels of terpenes and should be avoided, but most other wood chips, shredded or chipped bark, and sawdust are great brown mulches and work fine, especially if they are aged or if you mix in some form of organic nitrogen, such as green grass or even alfalfa meal, to ensure the C:N ratio is adequate and nothing need be borrowed by the microbes from the soil under the mulch.

How long mulch will remain effective depends on the kind of mulch used. For example, a 2-inch (5-centimeter) layer of bark chips will last about three or four years, as the lignin, cellulose, and waxes in the bark are difficult for microbes to decay. During this time, fungi will dominate. Leaves, on the other hand, can be completely decomposed in six months; fungi dominate at the start, but bacteria increase once they are able to get inside the material.

Leaves make great brown mulch. Photograph by Judith Hoersting.

Where and how you place mulches also plays an important role. Rule #7 (mulch laid on the surface tends to support fungi, while mulch worked into the soil tends to support bacteria) means it is possible to use one kind of mulch, say tree leaves, and get two different soil dominances. Bury most mulch, and bacteria will have an easier time. If it is on the surface, fungi will dominate the decay activity for a while because it is easier for them to travel from the soil to the mulch.

That is not all. The condition of the mulch is also important. If you wet and grind mulch thoroughly, it speeds up bacterial colonization (Rule #8). Bacteria need moist environments, or they go dormant. And if the material is ground up, it has a lot more surface area; increased surface area means it is easier to get into, and bacterial populations increase. To keep fungi from getting to their food source, some of these bacteria produce antibiotics that suppress fungal growth, making it easier for the bacteria to attain dominance once they get established. If you want more bacteria, use green mulches that have been ground up and soaked. If you only have brown mulch material and need to establish bacterial dominance, chop it into really fine bits and mix some in the top few inches of soil.

On the other side of the coin, coarse, dryer mulches support fungal activity (Rule #9). Mulches with less than 35% moisture are considered "dry mulches." Sure, fungi need some moisture to thrive and grow, but bacteria are more dependent on moisture. If you want fungal activity, use brown leaves or wood chips; don't pulverize them or wet them much; and place them on the surface.

## C:N ratio—again

In order to decay, mulch requires air, water, carbon, nitrogen, and the right biology; and once again, the ratio of carbon to nitrogen comes into play. If there is abundant carbon in mulch but not much nitrogen, or a ratio of 30:1 or greater, then the decaying microbes use up the nitrogen in the mulch and, once that is gone, will take nitrogen from the soils touching the mulch.

People make a big deal of this nitrogen "robbing," but it usually occurs only at the thin interface of the soil and the mulch. Although it has a real impact there, it usually doesn't affect the rhizosphere or the bacteria and fungi that reside there. Still, there is no reason to court problems. Experience has taught us that the chances nitrogen will be immobilized in soils under wood chip mulch can be reduced by making sure the chips are 3/8 inch or larger. This prevents much of the bacterial colonization you would see in smaller wood chips, and—

where mulches are concerned—it is primarily the bacteria that tie up the nitrogen in the surrounding soils.

## Applying mulches

Mulches are easy to acquire and relatively easy to handle and use in support of your soil food webs. Simply apply the rules and the appropriate mulch (green or brown; wet or dry; coarse or fine) in the appropriate way (dug in or on the surface) around your plants (vegetables, annuals, and grasses, or trees, shrubs, and perennials). Be careful: add a layer any thicker than 2 to 3 inches (5 to 7.5 centimeters) and you may end up blocking moisture and air and smothering mycorrhizal fungi. Do not put mulch snug up against stems or trunks; this can cause microbial decay of the plant itself, so back off a bit.

If you already use mulches on your property, you know what great things they can accomplish: keeping weeds down, holding in moisture during the summer, insulating soils in winter. They save a lot of work, don't they? Imagine how much more work they will save when you use them to help feed plants the kind of nitrogen they prefer. So correct any mulching mistakes you may have made and reapply the proper kind of mulch, in the proper way, to each plant type you have.

Mulches excel when they are used in conjunction with compost. Put the compost down first and then cover with mulch. As they do the soil, the compost organisms will inoculate the mulch, and begin to decay it as well.

Finally, you can foster all the bacteria and fungi you want in mulch, but if you don't also have the proper nutrient cyclers, specifically protozoa and nematodes, it is not going to have a big effect on your plants. You can actually grow your own protozoa by soaking fresh grass clippings, alfalfa, hay, or straw in dechlorinated water for three or four days. It is a good idea to bubble the water with an aquarium air pump and air stone (available at garage sales everywhere) to keep the mix aerobic. If you look carefully at this soup, you should be able to just make out protozoa dashing around (use a hand lens, and you're guaranteed to). Pour this protozoa soup on mulches, and you will increase the nutrient cycling power of the second soil food web gardening tool.

# Chapter 17
# Compost Teas

Compost tea—the third tool in the soil food web gardener's shed—puts the microbiology back into soils. This is a good thing because there are some practical problems associated with using the other two tools, compost and mulches. Besides the effort of turning a compost pile, if you have a decent-sized garden and lots of trees and shrubs, carting compost and mulches around and applying them can be hard work. You also have to have lots and lots of both if you are working on anything but a small yard. But the chief problems with these two tools? They take a while to reach the rhizosphere. And neither mulch nor compost sticks to leaves. Plants generate exudates from their leaves, attracting bacteria and fungi to the phyllosphere, the area immediately around leaf surfaces. As in the rhizosphere, these microbes compete with pathogens for space and food and in some cases can protect the leaf surfaces from attack. You cannot immediately introduce this microbiology into the rhizosphere, or into the phyllosphere at all, with compost or mulch.

Actively aerated compost teas, on the other hand, are usually easy to apply—to both soil and leaf surfaces—and are put right where they are needed. They are a fast, inexpensive, and definitely fascinating way to manage soil food web microbiology in your yard and gardens, handily overcoming the limitations of compost and mulch.

## What AACT is not

Do not confuse actively aerated compost tea with compost leachates, compost extracts, or manure teas, all of which have been employed by farmers and gardeners for centuries.

Compost leachate is the liquid that oozes out of compost when it is pressed or when water runs through it and leaches out. Sure, these concoctions get a bit of color and may have some nutrient value, but leachates do little to impart microbial life to your soils: the bacteria and fungi in compost are attached to organic matter and soil particles with biological glues; they don't simply wash off.

Compost extract is what you get when you soak compost in water for a

couple of weeks or more. The end result is an anaerobic soup with perhaps a bit of aerobic activity on the surface. The loss of aerobic microbial diversity alone (not to mention the risk of its containing anaerobic pathogens and alcohols) suggests that compost extracts are not worth the effort. We don't consider it safe or advisable to use them.

Manure tea, created by suspending a bag of manure in water for several weeks, is also anaerobic. Using manure is asking for pathogenic problems and, especially under anaerobic conditions, virtually assures the presence of *E. coli*. We want the beneficial microbes to be working in our soils and to get these, you have to keep things aerobic.

## Modern compost tea

Modern compost teas, on the other hand, are aerobic mixtures. If the tea is properly made, it is a concentrate of beneficial, aerobic microbes. The bacterial population, for example, grows from 1 billion in a teaspoon of compost to 4 billion in a teaspoon of an actively aerated compost tea. These teas are made by adding compost (and some extra nutrients to feed its microbes) to dechlorinated water and aerating the mix for one or two days. It is this mixing, or active aeration, that brings old-fashioned anaerobic compost teas into the modern era; it is also what keeps these compost teas aerobic, and thus safe. The air supply must be sufficient to keep the tea aerobic throughout the entire process.

It takes energy to separate microbes from compost. You know how much energy you have to use daily (or should) to remove another form of bacterial slime: plaque on your teeth. Bacterial slime in soils is just as strong. Consider, as well, that fungal hyphae grow not only on the surface of the compost crumb

| | |
|---|---|
| 10–150 µg | Active bacteria |
| 150–300 µg | Total bacteria |
| 2–10 µg | Active fungi |
| 5–20 µg | Total fungi |
| 1,000 | Flagellates |
| 1,000 | Amoebas |
| 20–50 | Ciliates |
| 2–10 | Beneficial nematodes |

Minimum standards for organisms per milliliter of compost tea. Courtesy Tom Hoffman Graphic Design.

Actively aerated compost tea is teeming with bacteria, fungi, protozoa, and nematodes extracted from compost. Photograph by Judith Hoersting.

but inside its nooks and crannies; you have to use energy to pull these strands off and out in addition to getting the bacteria "unglued." Of course, too much energetic action can kill these microbes. A brewer's action must be strong enough to tease out the microbes but not so strong that the microbes are killed once they are out of the compost and into the tea.

## The brewer

More and more compost tea brewers are on the market. These range from small, 5- to 20-gallon systems that can easily make enough tea to take care of a few acres (about 1.2 hectares) to commercial brewers capable of producing up to a thousand gallons or more of tea per brew. The Internet is a good place to look for compost tea brewers and compare them. Manufacturers should be able to show tests demonstrating that their machines can extract viable populations of fungi as well as bacteria. Only a biological test will tell you the numbers. Insist on seeing one, and if they don't have one, don't buy the machine.

You can also make an actively aerated compost tea brewer. It is very easy and our suggestion for those just starting with teas. All you need is one of those ubiquitous five-gallon plastic buckets; add to this an aquarium air pump (the biggest you can afford) and air stone, and about 4 feet (1.2 meters) of plastic tubing to use with it. The better pumps have two air outlets; if you cannot get a double-outlet pump, use at least two single outlet pumps. Sufficient aeration is critical. Once your system is operating, you will know if you have enough air. If the tea smells good, things are fine. If it starts to smell bad, the tea is going anaerobic.

We learned in physics that the smaller the bubbles, the higher the surface to air ratio and thus more air exchange with the water, but when bubbles get

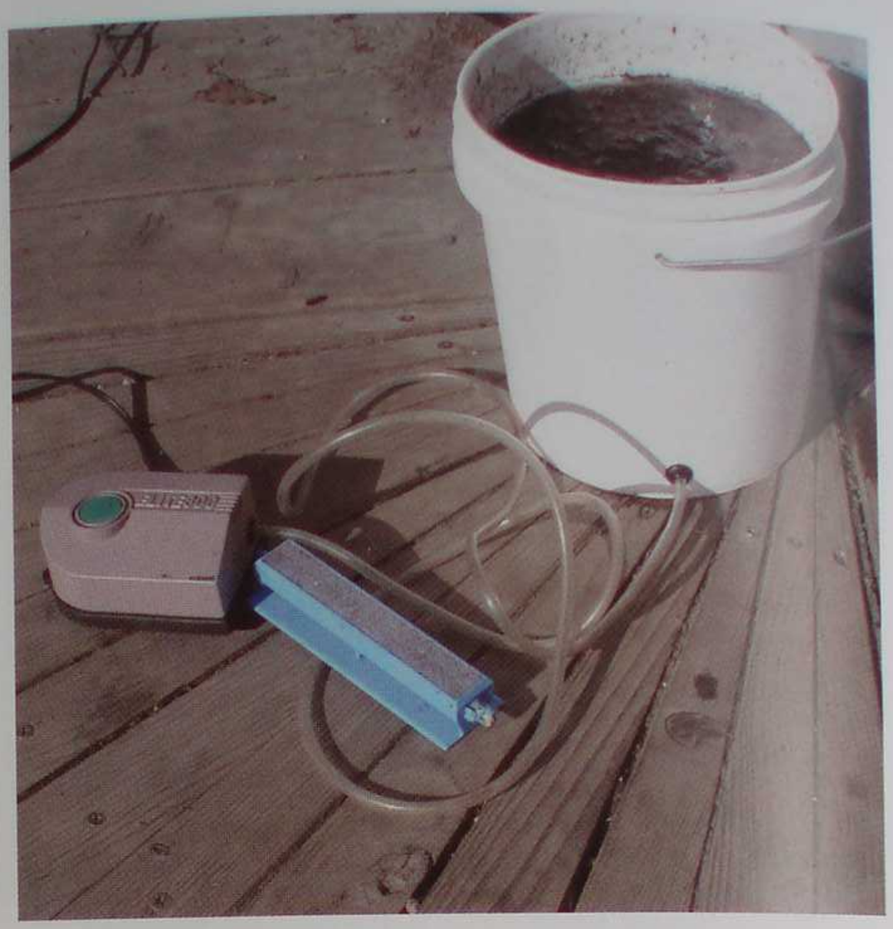
The KIS commercial brewer can make enough tea in 12 hours to treat a one-acre property. Photograph by Judith Hoersting.

The BobOLator, which uses a chamber to hold the compost, makes 50 gallons of tea in 24 hours. Photograph by Judith Hoersting.

too small, under 1 millimeter, they can cut up microbes. Aquarium air stones work well as long as you remember to keep them (and the plastic tubing that attaches them to the pump) clean. Another system can be made replacing the air stone with a two-foot link of ¼-inch soaker hose designed for drip irrigation systems. This hose can be coiled and taped onto the bottom of the bucket, giving better bubble "coverage" than an air stone.

Using a bit of duct tape, we tape the air stone or soaker hose to the bottom of the bucket, then connect the tubing and run it out of the bucket to the pump. If you want to have a really good-looking system, you can buy a small rubber grommet designed to be placed inside of the bucket wall so that you can thread the air tubing through it without having liquid leak out. If you put this low enough on the bucket wall, or even in the bottom of the bucket, it is easier to keep whatever you use to create bubbles down on the bottom of the bucket.

Some people put their compost in a porous bag before they put it into the tea brewer rather than allowing it to mix freely in the water. This eliminates the need to strain tea before you apply it, which you will have to do if you are going to use the tea in any garden sprayer (if you are only going to use tea as a soil drench, straining is not a problem). A pair of large-sized pantyhose works well as such a "compost sock." We'll save the male readers some research time: we



It is easy to make a simple actively aerated compost tea brewer using aquarium pumps and air stones. Photograph by Judith Hoersting.

learned by standing around and reading the labels at the store display that the largest pantyhose are often size Q. You can stretch the waist of a size Q all around the top of a five-gallon bucket, so that the legs fall into the bucket, and drop the compost right in the legs. Or you can tie the legs in a knot and fill the "bag" this creates with compost. It will sit in the water.

## Siting and cleaning the brewer

Temperature is important when brewing compost teas. If it is too cold, microbial activity slows. If temperatures get too high, then the microbes are literally cooked or go dormant. Room temperature is ideal. Keep track of the water temperature. This is one of the variables you can adjust later, if need be, and a record of this information will be helpful to the lab testing your samples. If you cannot site your brewer in a warm place with steady temperatures, then a small, inexpensive aquarium heater might be needed; these come with automatic thermostats. If it is too hot where you make tea, you may have to consider "packing" your bucket with ice or occasionally adding ice to it to keep temperatures down.

Compost tea should be made away from direct sunlight because its ultraviolet rays kill microbes. And, since the proteins (worm bodies, primarily) in compost have a tendency to foam in the tea, make sure you keep your brewer in a spot that can tolerate some spillage.

These black rings are bioslime that formed on the inside of a compost tea brewer basket. If allowed to remain, bioslime can detrimentally impact the quality of the tea produced. Photograph by Judith Hoersting.

It should be obvious but must be noted that it is important to clean up right away when making actively aerated compost teas. Bacterial slime is strong stuff and can clog the air holes in bubblers and tubing. This bioslime will appear in the strangest places. It will stick to the sides of the bucket and accumulate in the crevice at the bottom of the bucket. You may have to take apart hoses and fittings to clean them thoroughly. So, even before you use your tea, clean your system. If you get to it while it is still wet, you can usually wipe it off or "blow" it off with the force of water from a hose; at a minimum, flush it with water. Use a 3% hydrogen peroxide product or a solution of 5% baking soda to clean slime that has dried.

## Ingredients

Actively aerated compost teas contain lots of bacteria, fungi, nematodes, and protozoa because that's what's in compost. What makes these teas such a good soil food web tool (besides the high concentration of microbes) is that you can tailor-make AACTs to feed plants according to their specific needs by adding certain nutrients (see Rule #10). Use Rule #10, which applies equally to compost, mulches, and soil, when you make compost tea, and it evolves into Rule #11: by choosing the compost you begin with and what nutrients you add to it, you can make teas that are heavily fungal, bacterially dominated, or balanced. For many, the brewing process grows into a hobby in and of itself, not unlike making beer.

All recipes, however, start with the basic ingredients, the first being chlorine-free water. Rule #12 is very important: compost teas are very sensitive to chlorine and preservatives in the brewing water and ingredients. It is vitally important that none of the ingredients you use contain any preservatives. This makes sense. After all, these chemicals are intended to kill or discourage microbial life. If you are served by a water system that uses chlorine, you will need to fill your brewing container with water and run air bubbles through it for an hour or two. The chlorine will evaporate, making the water safe for microbes. Carbon filters and reverse osmosis water systems also work well to remove both chlorine and chloromines, and are particularly useful if you need large quantities of water. As a general rule, a carbon filter containing one cubic foot of carbon will filter four gallons of water a minute.

Next, you need to use good compost (forgive this redundancy: to us, all compost is good, or it isn't compost). Again, make sure there are no chemical remnants in it, and by all means give it the sniff test. If it doesn't smell good, it isn't good compost. Obviously, the best way to know is to have it tested. Avoid "almost compost," compost that hasn't finished the process or has gone stinky and anaerobic. Don't bother with compost that was allowed to overheat, killing beneficial microbes and reducing its soil food web. If you have a low diversity of microbes in your compost, you will have low diversity in your tea.

Vermicastings are a good substitute for compost. These are full of beneficial microbes and tend to be very bacterial (remember the role bacteria play inside the worm, digesting food), especially when they are fresh. For the initial five-gallon brew, you will need approximately four cups of either compost or vermicompost. You can use proportionately less compost the bigger the brew.

As for the extra ingredients, you can feed the microbial population while teas are brewing. Molasses (nonsulfured, so as not to kill the microbes) in powdered or liquid form, cane syrup, maple syrup, and fruit juices all feed bacteria in teas and increase their populations. Two tablespoons of any of these simple sugars in four or five gallons of water will help bacteria multiply and establish

| DECHLORINATED WATER | COMPOST |
|---|---|
| 25 gallons | 5 lbs (20 cups) |
| 50 gallons | 7 lbs (28 cups) |
| 500 gallons | 15 lbs (60 cups) |

The amount of compost (or vermicompost) used to make tea varies nonlinearly, as this chart shows. Courtesy Tom Hoffman Graphic Design.

dominance. If you make a bigger brew, add more nutrients in the same proportion: the amount of all added nutrients will vary linearly as you increase the size of your brew. More complex sugars and fish emulsion are also good bacterial food, though both will also support some fungal growth.

To encourage fungal growth in compost teas, add kelp, humic and fulvic acids, and phosphate rock dusts, which not only provide the fungi with nutrient value but also give them surfaces to attach to while they grow. *Ascophyllum nodosum* is a cold-water kelp that can be purchased over the Internet, at garden centers, and even animal feed stores, where it is often sold as powdered algae. The pulps of fruits like oranges, blueberries, and apples will also help fungi grow in compost teas, as will aloe vera extract (without preservatives) and fish hydrolysate (which is essentially enzymatically digested ground-up fish—bones and all). You can buy fish hydrolysate at some nurseries or make your own by adding papain (aka papaya peptidase) or kiwi (which also contains the appropriate enzymes) to a blend of fish to enzymatically digest the bones. Yucca and zeolites are also good fungal foods and do not support populations of bacteria.

## Give fungi a head start

Many new to tea brewing become frustrated because it can be difficult to grow fungi in quantities sufficient to make a balanced tea, much less a fungally dominated one. This is because bacteria not only grow but multiply rapidly in tea given adequate nutrition; whereas the brew time is almost never long enough for fungi to multiply in tea—they only grow bigger. The better way is to activate fungi in the compost prior to making tea, allowing populations to multiply before they are teased out of the compost and into the tea brew.

This activation is easily accomplished: several days before brewing the tea, mix the compost with simple proteins that serve as a good fungal food—such things as soybean meal, powdered malt, oatmeal, oat bran, or, best of all, powdered baby oatmeal. Thoroughly mix in one of these at the rate of three or four tablespoons per cup of compost. Make sure there is sufficient moisture in the compost, which is to say a drop of moisture can be squeezed out of a fistful of it. Put the mixture in a container, and place the container in a warm, dark place. A seed-germinating mat, placed beneath the container, works great to provide the proper heat.

After about three days at 80F (27C), the fungi in your compost, if you had sufficient numbers of them in the first instance, will have grown, and their invisible hyphal threads merged into a network of visible mycelia. The compost

Fungal mycelia are activated by adding fungal nutrients to compost before making tea. Photograph by Judith Hoersting.

should look like Santa Claus's beard, covered with long, white, fluffy strands. In a few more days, there will be so many fungal threads, the entire container of compost will be glued together.

## Teatime

Once you turn your machine on, the bubbles agitate the compost and start peeling microbes off and out of it. Depending on the compost and the nutrients, you may experience a bit of foaming; this can signal that worm protein is being released from the compost—a good thing. You can add mycorrhizal fungi at the very end of the brew cycle. If you put spores into the tea while it is being made, either they will be destroyed or the fungal hyphae they produce will be destroyed—they are both very fragile; also, since mycorrhizal fungi live off of root exudates, they and the tea must reach plant roots quickly.

It takes between 24 and 36 hours to develop a good tea using our simple bucket bubbler; some commercial brewers, with their high-energy systems, make tea in 12 hours. In any case, during the course of the brewing, tea turns coffee-brown, another favorable sign: the humates in the compost are being teased out into the tea. The temperature of the brew may also increase a few

degrees, a result of increased metabolic activity. The best part is the smell. The smell of compost teas, especially when molasses is used as a nutrient, is a healthy, sweet, earthy smell.

Compost tea has a very short shelf life. So many microbes now populate the brew that they quickly deplete the nutrients and start eating each other; more important, they are using up all the oxygen. If you are offended by the odor of a tea, it has probably gone anaerobic and should be discarded; do not toss it on your plants, for obvious reasons. It is best to use compost tea within four hours of manufacture, though it will last, diminishing in populations, for about three to five days if kept refrigerated or if you continue to bubble air through it.

After you have had some experience making teas, you may want to modify your machine in order to make better and better teas, meaning those that have higher numbers of microbes. For example, besides substituting the soaker hose for the air stone, we also upped the size of our pump; eventually we found a used, 1/3 horsepower air pump, and now make seriously bubbling tea in a 30-gallon plastic garbage can (affectionately known as the "Lawrence Welk–o-Lator"). The bubbles come from various pieces of equipment; we are continually experimenting, using specialized fish tank and Jacuzzi aerators, watering can heads, and even a plastic water pipe pocked with holes made with 1/16- and 1/8-inch drill bits.

## Application

Right at the outset we will tell you that you can never apply too much compost tea (our research shows no ill effects from unlimited applications). It doesn't burn plant roots or leaves, and the microbiology in the tea will adjust to the nutrients available at the site. Repeatedly applying compost tea will only help increase diversity of the microbial populations in your soils. Use tea on lawns, vegetables, trees, shrubs, annuals, and perennials. Unlike chemical sprays and soaks, compost tea is safe and easy to apply.

Once the tea is ready, apply it as a soil drench using a cup, a plastic watering can (bacteria can impact the zinc in metal containers), or (if the tea has been strained) a hand pump sprayer. Since compost teas will "stick" to leaf surfaces, you can inoculate leaves with a foliar spray of beneficial microbes. To be effective as a foliar spray, the tea must cover 70% of the leaf surface. Cover both sides of the leaves. When applying compost teas to soils, drench your plants and the area around them with the tea. You cannot overdo it.

And don't forget the sun: ultraviolet rays kill microbes. If you live in southern latitudes, you will want to apply before 10 a.m. or after 3 p.m., when UV

rays are weakest, even on a cloudy day. There is no microbial sunblock lotion. It can take 15 to 30 minutes for bacteria or fungal hyphae to attach themselves to a leaf (where they can get some protection)—far too long a period to be exposed to the sun's rays. Alternatively, spray with a drop diameter of at least 1 millimeter; with that much water, bacteria can develop enough slime to establish themselves before the water even evaporates. UV rays can also negatively affect the microbiology in soil drenches, but you can be a bit more relaxed about the timing of these since the microbes sink into the soil and leaf duff layer almost immediately.

Remember, you are dealing with living organisms here. The microbes you carefully cultivated and nurtured in your tea are very much alive and require gentle treatment. Sprayers must not exceed pressures of 70 pounds, and the velocity of the spray should be slow. Either stand back or turn the spray head up, so that the tea drops "parachute" down to the surfaces to be covered; there should be no forceful "splatting" of the tea onto the soil or lawn or plants, as this is what will sometimes kill the plant, not the pressure of the tank. Electrostatic sprayers, incidentally, may destroy microbes by putting the wrong charge on them, so test the tea from such a sprayer before using one.

It is possible to use a hand pump sprayer if you strain your tea, but you must take care not to strain the microbes out. The mesh of any "compost sock" should be at least 400 micrometers, which is big enough to let fungi and nematodes flow through but will keep out particulate matter that will clog conventional sprayers. Alternatively, you can decant a tea solution by letting it sit for 15 minutes after the aeration is stopped. This gets rid of a lot of the bits and pieces; the bad news is that often the amount of fungi in the tea is diminished.

You will be better off if you invest in a concrete sprayer, which is capable of handling the particles of compost that would clog a normal garden sprayer. Concrete sprayers look exactly like home garden pump sprayers, only with fewer bends, larger orifices, and nozzles that support bigger particles. For prices and availability, check with your local builders supply store, concrete contractor, concrete supply store, or sand and gravel company. A gasoline backpack mist sprayer is also appropriate, especially for a large yard. A great way to do a lawn is to use a traveling sprinkler with a fertilizer dispenser feeding tea into the water stream (see chapter 18 for more details).

Whether sprayed or poured, the microbes in the tea will establish themselves, grow, breed, attract predators, eat and be eaten, or go dormant. They create protective barriers around the roots and release nutrients when they die. They create and improve soil structure. They make protective barriers on leaves and compete with bad guys there as well.

Compost teas go to work immediately, and for this reason it is important that the tea applied be a good one, full of beneficial organisms, not diseases or pathogens. There is little room or tolerance for a poorly made tea. If you are not up to the job yourself, you can purchase AACTs from an ever-growing number of commercial nurseries and garden centers; some companies not only make but will apply compost teas for you. In either case, it is still advisable to ask for tests to see how the tea measures up and, of course, don't be afraid to give commercially made teas the smell test before buying or applying them. They may have started out fine but gone anaerobic before sale.

You can apply AACTs as often as you like, but how often you *need* to apply them (especially if you are paying for them) depends, as you can imagine, on the status of the soil food web organisms in the areas concerned. First-timers should get a base reading on microbiology and arthropod counts before "taking up" this very effective tool. As your soil food web becomes healthier, you'll need to apply tea less often. Thus, if your yard has had applications of chemical fertilizers for years, you should put down compost tea every other week for three months to establish a healthy soil food web population. Then you can start applying tea once every month for a season and, finally, three times a year.

How much compost tea should you apply in any given session? For two years one of us used about 60 gallons a week on a quarter-acre lot with positive results (save for a few complaints from a spouse that felt too much time was being spent teaming with microbes). The general rule, however, is to apply five gallons of compost tea per acre as a soil drench, ten gallons if you are going to spray leaves as well. It is fine to dilute the tea; just make sure there were five gallons when you started. When you are more experienced, you can match the amount of tea you apply with soil tests and tea tests to achieve specific fungal or bacterial ratios.

## Timing

There are certain times when it makes even more sense to apply a tea. For example, it is a good idea to apply teas immediately after leaves fall in the autumn. If the soil and leaf litter don't freeze in the winter, decay will proceed apace all winter long. Even with snow cover, decay will occur at the interface of the snow and the soil surface, where it will warm up enough for microbial activity to continue. Come spring, just before plants start their new growth, put down tea again: ten gallons of soil drench per acre is our suggestion. Treat opening buds and young leaves to a foliar spray of five gallons per acre, as well. If your plants are thriving and are disease-free, you need apply tea only at these

Powdery mildew growing on leaves. Compost tea sprayed on leaves can outcompete this and other fungal diseases. Courtesy Clemson University, USDA Cooperative Extension Slide Series, www.forestryimages.org.

Powdery mildew up close. Image copyright Dennis Kunkel Microscopy, Inc.

two times; if you live in a tropical environment, you should apply tea four times a year.

When it comes to outcompeting disease organisms in the soil or phyllosphere, fungally dominated teas have been used to prevent and suppress the growth of powdery mildew (*Erysiphe graminis* on turf, *Phytophthora* spp. on rhododendrons), downy mildew (*Sclerophthora* spp.), take-all (*Gaeumannomyces* spp.), gray snow mold (*Typhula* spp.), pink snow mold (*Microdochium* spp.), red thread (*Laetisaria* spp.), crown and root rots and damping off (*Pythium* spp.), brown patch (*Rhizoctonia solani*), summer patch (*Magnaporthe* spp.), rusts (*Puccinia* spp.), and fairy rings (all sorts of fungi).

Bacterially dominated teas have been useful in outcompeting pathogens in mild cases of dollar spot (*Sclerotinia* spp.—severe infestations also require lots of fungal competitors), necrotic ring spot (*Leptosphaeria* spp.), yellow patch (*Rhizoctonia cerealis*), leaf spots (*Bipolaris* spp., *Curvularia* spp.), pink patch (*Limonomyces* spp.), and stripe smut (*Ustilago* spp.). Insects too succumb to the effects of compost teas, specifically weevils, grubs (*Ataenius* spp.), cutworms, and chafers; several reports attest to negative impacts on whiteflies, fire ants, and scale.

At the first sign of disease or insect infestations on any of your plants, apply teas and repeat in five to seven days. Obviously, a prophylactic application

Root rot and damping off (shown here on bent grass host) can also be controlled by applications of actively aerated compost tea. Courtesy Clemson University, USDA Cooperative Extension Slide Series, www.forestryimages.org.

is best: if you have a sense of your yard's phenology (seasonal cycles), you should be able to apply teas in advance of breakouts.

Finally, certain weeds are affected by compost teas. Clover and quack grass have a tougher time of it when you add lots of protozoa and beneficial nematodes to the soil; this teas do and increase nitrogen cycling. Plantains, chickweeds, and nut sedges disappear if you reduce the nitrates in soils: use a fungally dominated tea. Ivy also responds to highly fungal teas.

Compost teas are a veritable liquid soil food web. Instead of lugging around wheelbarrows of compost, consider compost teas, a concentration of the same microbiology. When you use them, you are really teaming with microbes.

# Chapter 18

# The Lawn

USED TO BE, if you were not happy with the way your lawn looked, you put down manure or top-dressed with compost. If you had weeds, you or your children eradicated them by hand. All that changed in 1928 when a company that sold grass seed came up with a way to make synthetic, nitrogen-based fertilizers and to do so cheaply. The rest is history: through aggressive advertising, and let's face it, fantastic results, the chemical side of lawn care has grown into a multibillion-dollar industry.

## A vicious cycle

Chemical lawn fertilizers work, and they work well. Their concentrations of nitrates are so high, they are immediately effective: fertilizers are chemicals that feed the roots directly, bypassing the biology in the soils. However, applications of synthetic fertilizers kill off most or all of the soil food web microbes (Rule #13). These fertilizers are salts, and when they come into contact with soil microbes, they cause osmotic shock—that is, water in the cells of these organisms flows to the higher concentration of salts without, literally bursting through cell walls and killing off the microbes that hold (bacteria and fungi) and cycle (nematodes and protozoa) nutrients.

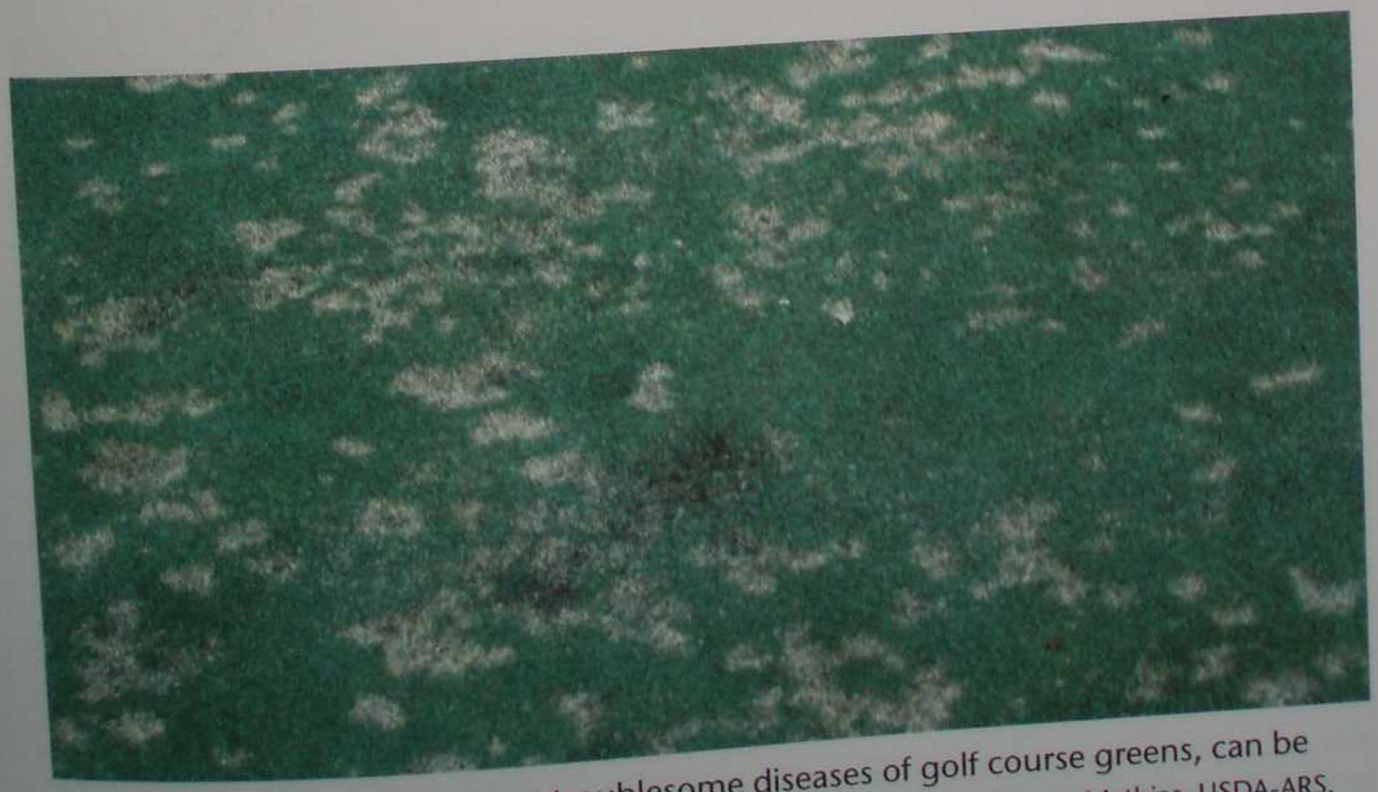
How quickly a lawn's soil food web organisms are affected by chemical fertilizers depends on the organisms in question, their concentration and strength, and the amount of fertilizer applied. A good rule of thumb, however, is that 100 pounds of nitrogen lawn fertilizer per acre will wipe out a healthy soil food web. Lesser quantities kill fewer members of the soil food web, but do damage it nonetheless. What isn't killed outright by four 25-pound bags of lawn fertilizer is driven from the acre by its lack of food resources or by the odor of the chemical fertilizers themselves. When microbiology is missing, as you know, you have to apply (and reapply) the nutrients necessary to keep the grass green.

With the natural buffering action of bacteria and fungi lost, a soil's pH is thrown out of whack; soil pH gets lower and lower as more nitrate salts are

applied, eventually requiring readjustment. Matters are made even worse by the common practice of removing grass clippings while or immediately after mowing. The chemical gardener is usually one that "cleans up" after mowing, and even the organic gardener all too often has the knee-jerk urge to rake grass clippings. By removing clippings and autumn leaves, a gardener unwittingly compounds the destruction of life in the lawn's soil. Then again, if you don't have a soil food web to break down and decay leaves and clippings, you are compelled to remove them so they won't block the light the lawn needs.

The use of chemical fertilizers sets off a vicious cycle, then: the more fertilizer you use, the more the soil food web is destroyed, and the more fertilizer you'll need to fill the nutrient void you've created. It is a downward spiral. The end result is either a lawn in really terrible condition or a gardener who has to do a lot of work. Removing the clippings from and applying salts to a lawn leaves the gardener, alone, to do all the work that was formerly carried out by the trillions upon trillions of microbes who used to be on the job. Earthworms leave the area when salts are applied; salts are irritants, and the gut microbes responsible for worm digestion die if fertilizers are ingested. The fungi that bind soil aggregates are gone. The bacteria that produce the slime that binds individual soil particles into aggregates are gone. The lawn's soils lose structure. Slowly, they lose the ability to hold air and water. It is soon Katy-bar-the-door time, and more diseases and problems will arise.

Without a well-populated soil food web, natural defenses are gone. Lawns infested annually with mildew, black spot, rots, gray mold, and other disease-



Dollar spot, one of the two most troublesome diseases of golf course greens, can be caused by excessive nitrates in chemical fertilizers. Photograph by Kevin Mathias, USDA-ARS.

causing opportunistic microbes clearly lack the diversity of beneficial organisms that would normally keep these things in check. By teaming with microbes, you can have a healthy and attractive lawn—with a lot less work on your part.

## Taking stock

As with any other area of the yard, it is important to first determine the status of your lawn's soil food web. Biological soil tests by a competent lab are the only accurate way to learn what needs to be corrected and exactly how much restoration work you have to do, but other things will give you a pretty good indication of its state. Earthworms, for instance, won't be present if there are no bacteria, fungi, and protozoa to eat; their presence, therefore, is an excellent indicator of a healthy food web. If you have a good population of worms, your lawn already has lots of beneficial organisms building soil structure, cycling nutrients to the grass roots, building water- and air-retention and drainage capacity, and fighting pathogens. So, if you see birds hunting for earthworms, lots of earthworms after a good rain, or worm castings deposited on the lawn's surface at night, you probably have only to maintain the lawn's soil food web, not add microbiology to establish one.

A lawn maintained by the soil food web. Note the yellowish back area, which was not treated. Courtesy Soil Foodweb, Inc., www.soilfoodweb.com

Similarly, your lawn's soils should contain plenty of microarthropods—the little arthropods you need a hand lens, MacroScope, or light microscope to see. These help with nutrient cycling, open up the grass clippings, and help aerate the soil. Use a Berlese funnel; if you discover that your soils are lacking these members, you can restore the microbiology by providing beneficial fungi, bacteria, protozoa, and nematodes—the base that will attract arthropods, worms, or other soil food web participants that are missing.

## The care and feeding of microbes

At the beginning or end of the growing season, spread an organic fertilizer (microbe food, really) on your lawns. This will ensure that there is a sufficient supply of organic matter to feed the microbes in the soil. Microbe food? This is a big but necessary change in gardening terminology. When you team with microbes, you feed them, and they feed the roots.

Rule #14 warns that if you want to work with the soil food web, you need to stay away from additives that have high NPK numbers. Most gardeners know these letters represent the percentages of nitrogen, phosphorus, and potassium in the fertilizer, and this NPK trilogy appears on all fertilizer packaging. Don't put anything on the lawn with NPK numbers greater than 10-10-10; traditional organic fertilizers usually meet this criterium. Of particular note is that a high (anything over 10) concentration of phosphorus not only prevents mycorrhizal fungi from growing but kills off the ones that are there. As a result, the grass loses its ability to take up a resource easily, and no matter how much

Mycorrhizal fungi (see bowl on the right!) help lawns grow. Courtesy Mycorrhizal Applications, www.mycorrhizae.com.

phosphorus you put on the lawn, it is locked up quickly and unavailable to the mycorrhizae-less grass plants.

Our favorite microbe food for lawns is soybean meal with an NPK of 6-1-1. This is applied at a rate of 3 or 4 lbs per 100 square feet. Other useful organic microbe foods include alfalfa meal, blood meal, cottonseed meal, feather meal (all applied at the rate of 4 lbs per 100 square feet at first and then adjusted to taste) and fish bone meal (3 lbs per 100 square feet—but we warn you, there will be a heavy fishy smell for a few days). These all feed the soil biology; they are not absorbed by plant roots—hence, microbe food, not fertilizer.

It also helps to encourage a suitable environment for the lawn's microbes. We know from Rule #2 that lawns prefer slightly bacterially dominated soils. For this reason alone it is a good idea to leave grass clippings on the lawn, all season, as a bacteria-favoring mulch. The sugars in the grass will attract a healthy population of bacteria. Clippings also foster populations of protozoa, which ensure nutrient cycling. And you will have to mow less, now that high amounts of concentrated nitrates are not being sucked up into by plant roots.

When leaves drop at the end of the season or when twigs and small branches fall after a storm, do not rake them. Instead, mulch them up in place by running your lawn mower over them once or twice. This will open them up and make them available to the fungal components of a lawn, which are also important; fungi help provide structure and drainage and help with the harder-to-digest grass stems that can build up to a thatch layer in their absence. This is why you should rejoice when you see mushrooms in your lawn. They are usually a sign that things are healthy beneath the green grass.

Lawns that have not had the benefit of a healthy soil food web (which may be attributable as much to poor drainage as to chemical fertilizers and weed killers) should be plug-aerated, a procedure wherein 2-inch-long plugs of soil

A handful of plugs pulled from a lawn during aeration. Photograph by Judith Hoersting.

are pulled from the lawn, creating holes throughout. These holes open up the lawn, allowing water, air, and organic food to enter the root zone. The plugs should be left on the lawn and allowed to decay.

Plug aeration in the early spring every three or four years will help the soil food web because it helps repair compaction caused by the weight of snow and ice or the back-and-forths of pets, children, and vehicles. The aeration is particularly useful in keeping the lawn's fungal population healthy: as the most fragile, fungi are also the first soil organisms to go when a lawn becomes compacted, as it inevitably does. After this spring aeration, apply an organic microbe food. This will fall into the plugholes and provide food down in the lawn's root zone.

Next, inoculate the lawn with beneficial microbes to put microbiology back into the soil or to maintain what is already there. If the lawn is small, this is easily accomplished by applying a thin (up to a half-inch) layer of bacterially dominated compost to the lawn with a fertilizer spreader. If the lawn is large, apply a slightly bacterially dominated compost tea (see "Applying Compost Tea to Lawns" later in this chapter).

What about chlorine in the water you use to water your lawn? It shouldn't affect microbes if you water using a sprinkler. The fine mist spray and the trip from the air to the ground helps clear most of the chlorine from this water. Of course, you can buy an inexpensive chlorine filter and install it on the outside hose bib. One filter should last all season, but you should check the output occasionally to be sure.

## Weeding the soil food web way

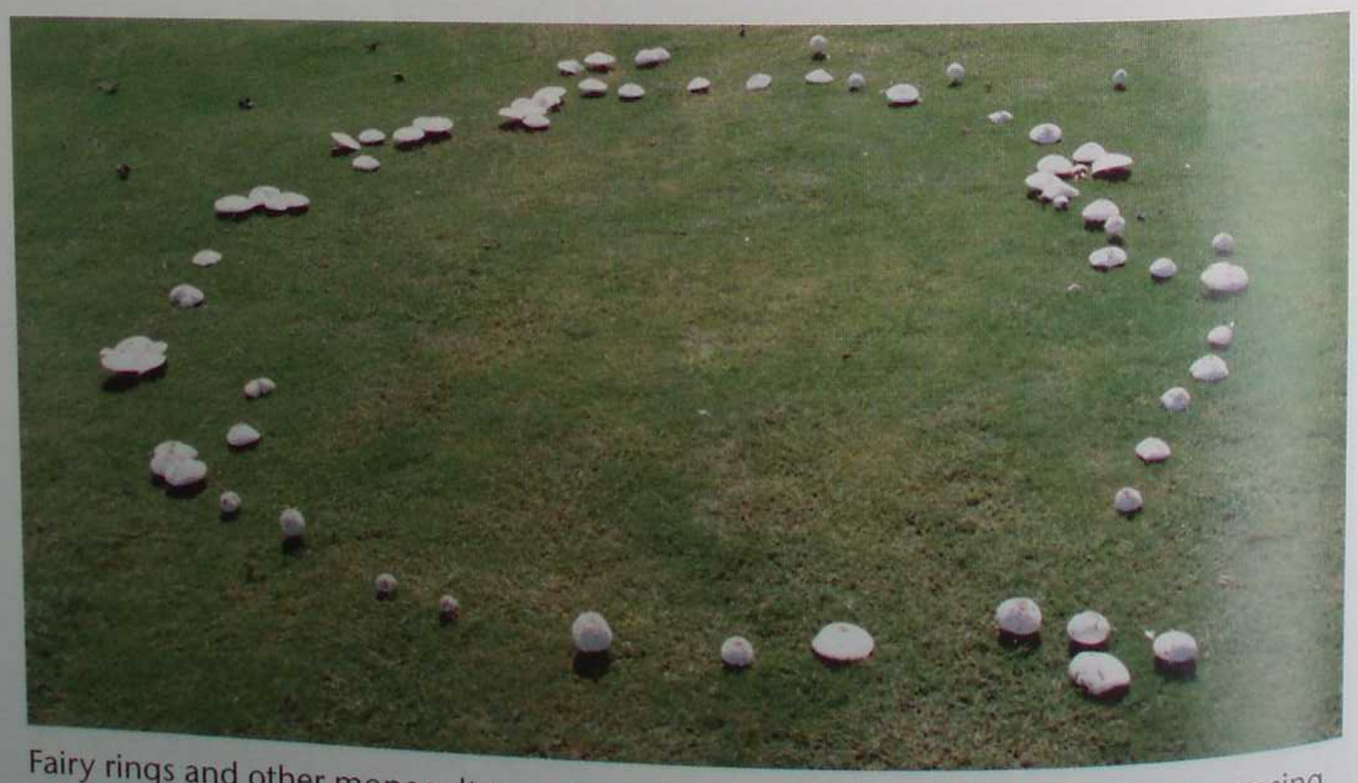
Lawn weeds can be influenced by the soil food web. Dandelions, for example, appear in calcium-poor soil surfaces. Their long taproots seek out the calcium they lack, and the calcium is deposited in the soil when the dandelion dies. In time—unfortunately, sometimes quite a long time—the soil food web biology works this calcium into the upper layer of soil, where it has been missing. In essence, dandelions can mine themselves out of existence. To get rid of dandelions sooner, boost fungal activity in the soils; fungi tie up calcium, much more so than do bacteria. You can also use a microbe food, corn gluten (a by-product of corn starch production), as an organic, preemergent agent. Put it on lawns with dandelions or other weeds just as they are coming to seed, and it will prevent the new seeds from developing secondary roots. In the meantime, its 10-10-10 formula feeds the soil food web.

Lots of clover or quack grasses in a lawn indicates that the soil food web is

not cycling enough nitrogen. Adding nematodes and protozoa via compost, compost tea, or a protozoa soup can increase nitrogen cycling. Chickweed, a frequent weed in lawns, thrives when there is too much nitrate, which is what you get when you put down a commercial lawn fertilizer. Stop applying chemical fertilizers; instead, use the soil food web tools to increase the fungal biomass (and hence the available ammonium) in your lawn.

Moss, on the other hand, indicates that your lawn soil is already fungally dominated instead of being slightly bacterial, as lawn grasses prefer. Mosses like acidic conditions. Apply very bacterial teas and a thin topdressing of very bacterially dominated compost to moss-infested lawns, and the pH will gradually change to one "acceptable" to grass and not as "acceptable" to moss. This will lessen and eventually prevent the appearance of new moss. You should remove the existing moss with a thatching rake and may have to apply iron to kill it first.

As a "soil food webbie," you already know you should be happy to see mushrooms in your lawn. Not too many, of course, which would mean you need to apply a bit more bacterial tea. If you are worried about fairy rings, for example, just increase the diversity of the fungi in your lawn soils by making sure your teas and compost have a good diversity of fungi; the fairy ring fungi should then be outcompeted. In addition, recognize that micro- and macroarthropods as well as mice and shrews eat these and many other fungi, keeping them in check.



Fairy rings and other monocultures of fungi in the lawn can be overcome by increasing diversity with compost or compost tea. Courtesy Clemson University, USDA Cooperative Extension Slide Series, www.forestryimages.org.

## Easy changes and good starts

You can use the soil food web to your advantage when it comes to changing pH. Normally you would have to put down hundreds of pounds of lime, gypsum, or sulfur to alter soil pH a few points in a decent-sized lawn; lime in particular acts slowly, taking a season to effect even a point's change. However, you can use considerably less (about one-quarter the amount) and take less time to get the same results by applying some soil food web science. Instead of putting it directly on the lawn, mix lime in when you are making compost. It will be tied up by the microbes in the compost and released during the normal food web cycling. You can put this compost directly on the lawn or you can make compost tea.

Obviously, if you are just putting in a lawn, you have an opportunity to establish a healthy soil food web from the very start, sparing your lawn the indignity of chemical addiction. Before you broadcast grass seed, mix it with the type of endomycorrhizal fungal spores associated with grass plants, vesicular-arbuscular mycorrhizae (VAM). A healthy lawn should have a good portion of roots colonized by VAM for the lawn as a whole to get the benefits of the mycorrhizal relationship. VAM colonization helps grasses compete with weeds for nutrients and blocks root-eating nematodes. And mycorrhizal fungi bring both water and nutrients back to the roots. Biological testing labs can tell you how much VAM you have in your existing lawn soils.

Twenty-four hours prior to seeding a lawn, roll wet grass seed in VAM and store it in a dark, cool spot. VAM will help achieve a healthy lawn that does not need watering or feeding as frequently as those without mycorrhizal fungi.

## What if you need a quick fix?

Some lawns are seemingly hopeless, and while soil food web management eventually prevails, quicker action is sometimes desired. Consider first the use of heat, vinegar, or manual labor to get rid of weeds in lawn; if weeds are so bad that you need to use a herbicide, or if the lawn needs an instant nitrate greening (say, for an emergency backyard wedding), then you should take remedial action to restore the soil food web.

Always practice Rule #15: follow any chemical spraying or soil drenching with an application of compost tea. Give the stuff a few days to work, and then apply the tea. The microbes in the tea will immediately start to detoxify the soil by breaking down the remaining chemicals and repopulating it. Repeat in a week, and check the status of soil food web life.

Both bacteria and fungi can degrade pesticides, but it is mostly the fungi that attack and break up these complicated chlorinated carbon rings. You therefore need to inoculate contaminated soil with lots of organic food resources with complex proteins (the kind fungi like), such as kelp, fish hydrolysate, and humic acids.

## Applying compost teas to lawns

One of the best ways to establish the right biology in lawns is to use a slightly bacterial aerated compost tea at a rate of five gallons per acre. We are the first to admit that applying compost tea to a large lawn can be problematic if you don't have the right equipment. A commercial tea sprayer service is the easiest way but can be more difficult to arrange and much more expensive than applying it yourself.

Concrete sprayers (see chapter 17) are fine for a small area. For larger areas, you should consider a traveling sprinkler (one that follows along a hose laid out on the lawn) with an inline fertilizer dispenser (a tank made for applying soluble fertilizers) attached to your water source. Instead of holding fertilizer, the dispenser can be filled with actively aerated compost tea, which it will feed to the sprinkler as it travels across the lawn.

A commercial tea sprayer service pays a call. Photograph by Judith Hoersting.

A traveling lawn sprinkler and a fertilizer dispenser make applying tea to a lawn easy work. Photograph by Judith Hoersting.

If you plan on applying tea to a really large lawn, you might want to consider renting or buying a gas blower (and using its lowest, most gentle setting). You can mist an acre of lawn in about five to ten minutes and spray up into 30-foot trees. Rental is the best idea, as you will only need applications in the spring and autumn once the soil food web is established. Do ensure the tank is free of any residual herbicides, pesticides, or other harmful chemicals.

Once your lawn has a thriving soil food web system, it will be much easier to care for. You will no longer have to thatch or rake clippings or leaves. You will need to water less, mow less frequently, and best of all, have the satisfaction of being able to play and work on your lawn without worrying about dangerous chemicals.

Chapter 19

# Maintaining Trees, Shrubs, and Perennials

TREES, SHRUBS, AND PERENNIALS are the mainstays of any yard's landscaping. Yet they seldom get specialized care and are instead lumped in with the lawn. Whatever fertilizer goes on the grass is usually all the trees and shrubs receive, and all many perennials get as well. The roots of trees and shrubs and some perennials run under the lawn, and they are affected by traffic and by the use of nonselective herbicides, which besides killing lawn weeds kill even the beneficial organisms that protect plants. With a diminished soil food web, you have to become their defenders and continue to feed trees, shrubs, and perennials.

## Trees, shrubs, and perennials prefer fungally dominated soils

Ever wonder why the lilacs never bloom? or why that spruce didn't survive when you planted it in the middle of your beautiful green, nitrate-fertilized lawn? Remember, Rule #3 dictates that trees, shrubs, and perennials prefer their nitrogen in the form of ammonium, not nitrate. This means fungal soils. Lawns, on the other hand, do best with nitrates or slight bacterial dominance and therein lies the problem. If the soil is very heavily bacterial, many trees have a difficult time establishing themselves.

Being surrounded by lawns may not be a good thing for trees, shrubs, and perennials—or the gardener—unless some soil food web management practices provide a different soil food web specifically where they grow. We realize that trees and shrubs in particular often function as specimens in the landscape, and that a conifer, for example, that craves ammonium nitrogen might be sited in the middle of a lawn that prefers nitrates. The trick, then, is to try to create an island around each tree and shrub with a fungally dominated soil food web.

The few exceptions to Rule #3 are the trees and shrubs normally considered transitional in the successional development of ecosystems from desert through old growth forest. The most familiar of these are cottonwoods, birches, and

Trees growing in a bacterially dominated or balanced environment should benefit from mulch that will attract fungi. Photograph by Judith Hoersting.

aspen. These do well in bacterially dominated soils when they are young because at that stage of their development they can easily utilize nitrates. Once mature, however, even these prefer ammonium nitrogen.

## Trees, shrubs, and perennials dislike compacted soils

Trees, shrubs, and perennials are frequently the victims of compacted soils, especially when they are planted in lawns (as is often the case with trees and shrubs) or in pathed gardens (as with perennials). Every precaution should be taken to prevent this condition (and every step taken to correct it), as roots (and thus plants, obviously) do best in soil with good structure, and good soil structure as you now know absolutely requires an active soil food web.

Larger organisms cannot survive in compacted soil—they cannot move through it in search of food because transportation pathways have been destroyed; if the compaction is really severe, it may be impossible to establish new ones, or not worth the bother. With the nematodes and many of the protozoa gone, nutrients accumulate in fungal and bacterial biomass instead of being released and available to plants. At the same time, the fragile mycorrhizal fungi

associated with the roots of trees, shrubs, and perennials are literally crushed or drowned; mycorrhizal fungi that compete with *Pythium* and *Rhizoctonia*, two fungi that cause stem and root rot problems, for example, are missing. After a while, the only soil food web organisms left are the bacteria and opportunistic fungi and protozoa that are so small in size they are able to move through even compacted soil. The food web is not in good shape and surely not full of fungi as trees and shrubs prefer.

Plant roots too have trouble moving through compacted soil. And since they can no longer rely on mycorrhizal fungi to bring back nutrients, plants face a double whammy in compacted soils: they not only don't get the kind of nitrogen they prefer, but their access to water and phosphorus and other nutrients is limited. They become even more stressed.

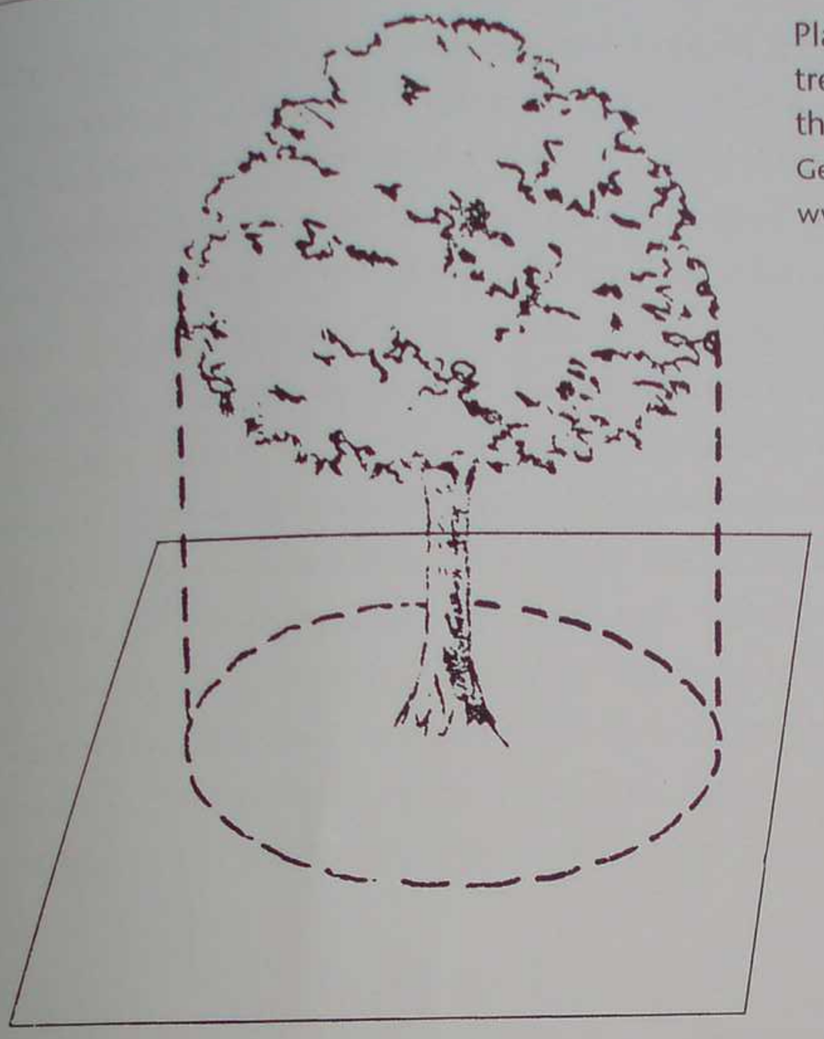
It gets worse. Compaction reduces oxygen levels, and anaerobic bacteria take over. Anaerobic bacteria produce metabolic products that kill roots. The tunnels and burrows through which water flows, pulling and pushing air, disappear. No mycorrhizae, no beneficial fungi, harmful elements galore—this is not a healthy situation.

Plug aeration of the affected area is only a first step toward remediation of compacted soils. If you don't have the proper soil food web organisms to improve compacted soils, the benefit of aeration will be short-lived. The solution is to apply food web management practices and return the organisms that are needed to build and maintain soil structure. Mulches, compost, and compost teas are all very effective when it comes to treating compacted soil around trees, shrubs, and perennials.

## All three soil food web tools apply

Brown mulches and fungal compost and compost tea work best when caring for trees, shrubs, and perennials. Start with compost and place it under all trees and shrubs and around all perennials to a depth of 1 to 2 inches (2.5 to 5 centimeters). Go at least out to the drip line of the tree or shrub, but make sure the compost doesn't touch the stem or trunk of any of these plants (so that, again, the microbes in the compost don't attack the bark). Obviously, you should give up on trying to grow grass under trees.

Gravity isn't the only reason trees and shrubs drop their leaves where they do. The nitrogen and carbon in these leaves is naturally recycled, and some makes its way back into the plant. Nature places mulch over tree roots; you should too—again, to at least the drip line—using brown mulches. Mulch even if you don't have compost to put under your plants. Start with the plant's own



Place compost and mulch under trees and shrubs at least as far as the drip line. Diagram by Tom Hall, Georgia Forestry Commission, www.forestryimages.org.

leaves if you can (open these up for bacteria and fungi by running them over with a lawn mower); don't remove them. Add to nature's mulch with brown mulches of any kind, but don't let it get too deep. A few inches is all that is needed to support a healthy population of fungi. The mulch has the added benefit of keeping down weeds and grass by blocking the light.

Finally, consider an application of compost tea around trees, shrubs, and perennials, once at the beginning of the growing season (two weeks before trees and shrubs leaf out) and again at the end, just as leaves finish falling and are in place under the plants. The microbes in the tea will really speed up decay during the winter months and support a good, fungally dominated food web community. You can simply soil drench, and don't need to bother with sprays, except for perennials, which in addition to the two soil drenches should be sprayed at least once after their leaves appear to add microbiology to the phyllosphere.

## Mycorrhizal relationships

Before planting trees, shrubs, and perennials, inoculate them with mycorrhizal fungi. These can be purchased at nursery centers. Remember, there are two basic types of mycorrhizae—those associations where roots are invaded, and

those where they are not—so it is important you get the right ones. Which mycorrhizal fungi to use on what is answered by Rules #16 and #17: most conifers and hardwood trees (birch, oak, beech, hickory) form mycorrhizae with ectomycorrhizal fungi; most shrubs, softwood trees, and perennials form mycorrhizae with endomycorrhizal fungi. These rules are based upon the research of soil scientists, who now have the tools to assess what types of fungi naturally associate with particular plants and have codified these assessments. There are exceptions to these rules. For example, plants in the heath family, which includes rhododendrons, azaleas, and blueberries, require ericaceous mycorrhizae, which are not yet commercially available. Nonetheless, if you stick with these rules, you should be on stable (but, we hope, not compacted) ground.

Mycorrhizal fungi spores must come into direct contact with roots within 24 hours of being exposed to moisture in order to grow. Commercial preparations that contain mycorrhizal fungi are always dry powders or grains (mixed with various materials to help in their delivery), so they are easily applied when

**Mycorrhizal spores.** Courtesy Mycorrhizal Applications, www.mycorrhizae.com.

**The pine on the left was treated with mycorrhizal fungal spores when planted; note the increased size of both the seedling and its root ball.** Courtesy Mycorrhizal Applications, www.mycorrhizae.com.

plants are about to be put into the ground. Simply sprinkle them on the roots or dip the roots directly into the spores before you plant, and then water in the new plant as usual.

Existing trees and shrubs are a bit more difficult to colonize. Let's hope your soils have not been degraded to the point that natural mycorrhizal fungi have been affected. Look for signs of mycorrhizae in the form of one particular kind of mushroom growing near the same kind of tree. Birch trees, for example, often form an association with the fly agaric, *Amanita muscaria.* If your existing trees have mushrooms under their drip line, you most probably are looking at an existing mycorrhizal association and don't have to add to create one.

If you have a yard with really compacted soils, have not seen mushrooms around your trees and shrubs, or have noticed they are not doing well, consider using a root feeder or long syringe (the kind used to apply glue) to inoculate the roots of existing plants with the appropriate mycorrhizal fungi. In the case of most perennials and shrubs, you can carefully dig into the root zone with a spade or trowel and apply endomycorrhizal spores whenever you come across roots.

Birch trees often form mycorrhizae with the mushroom *Amanita muscaria*. Photograph by Judith Hoersting.

## Unstressed plants are healthier

Stressed trees put out a signal recognized by aphids and other insects; they know the tree is weak and attack it. Unstressed trees don't emit this message, and they are able to produce extra pitch and sap to trap any invading beetles. Their exudates attract all the right microorganisms. Their leaves are coated with beneficial bacteria and fungi to outcompete disease. Their roots have formed mycorrhizae that increase their reach and allow them to dine on phosphorus and wash it down with ample water.

The bottom line when it comes to caring for your trees, shrubs, and perennials: try to plant them in soils that are already fungally dominated. If not, apply fungally dominated compost, mulches, and teas to and around them. Let leaves remain under the plants from which they drop. And, obviously, use all three soil food web tools, especially compost teas, at the first sign of any diseases.

Chapter 20

# Growing Annuals and Vegetables

A WHOLE INDUSTRY is built around fertilizing annuals and vegetables. The lawn might be the number one dump for chemical fertilizers, but homegrown tomatoes and marigolds are not that far behind. The same high concentrations of soluble nitrates that work on the lawn, with their percentages tweaked a bit, work quite well when it comes to feeding flowers and vegetables; and the vicious cycle that develops in lawns treated with chemical fertilizers will also occur in your flower and vegetable beds. The natural cycling of nutrients ends. You have to feed the plants you grow with increasing amounts of chemical fertilizers because no longer are there microbes to provide them with nutrients, and in the absence of microbes, soil structure deteriorates. Without a healthy soil food web, opportunistic pathogens and animals appear, and these seemingly require other chemicals to keep them at bay or in balance.

## Annuals and vegetables prefer bacterially dominated soils

What are the soils in your vegetable and flower beds like? Look for earthworms. They survive by eating protozoa and bacteria, and, as with lawns, if you have lots of earthworms and earthworm castings in your soils, then you probably have bacterially dominated soils with plenty of nitrates, which are what most vegetables and annuals prefer (remember Rule #2). Set up the Berlese funnel and see what kinds of microarthropods are roaming the soils. You want to see lots of bacteria-eating mites and good diversity of animals. Measure your soil's pH in the rhizosphere. If it is decidedly alkaline, you most probably have bacterial dominance. Similarly, an acidic reading means you have fungi and probably fungal dominance. Finally, get your soil tested for its microbiology; this is the best way to know what is missing, if anything. Sure, an NPK test won't hurt, but it is really the biology you need to know about.

## No more rototilling

If you are an organic gardener you probably already employ one or two of the soil food web tools. But there is one traditional organic practice we must ask you to drop. With one exception we recommend the no-dig principle: never rototill again. This is a real shocker to those who regularly rototill or otherwise turn their soils. Soil turning is so ingrained in the psyche of the home gardener that Rule #18 is a special rule against it: rototilling and excessive soil disturbance destroy or severely damage the soil food web. They are outmoded practices and should be abandoned in established garden beds. This is heresy in most gardening circles. Many organic gardeners advocate rototilling and double digging as ways to mix organics back into the soil; indeed, rototiller manufacturers are major advertisers in magazines that promote organic gardening.

The age-old agricultural practice of plowing the earth really picked up steam, so to speak, when lawyer Jethro Tull (1674–1741) inherited a farm in southern England and invented a seed drill that mechanically placed seed at a set depth in a premade hole, replacing hand-broadcasting. Tull also actively encouraged farmers to loosen soil before planting crops; he had noticed that vegetables did better in loosened soil and from this concluded that plant roots possessed little mouths and ate soil particles (how else could a plant ingest nutrients?). Believing that loose soil consisted of smaller particles that would more easily fit into root mouths, he developed a horse-drawn hoe to put his theory into practice. His writings later caught the attention of gentlemen farmers like George Washington and Thomas Jefferson, who encouraged their fellow Americans to break up soils. The end result is that most home gardeners still break up and turn over their soil at least annually, even though we know plant roots don't eat soil.

For reasons unknown to Tull and his contemporaries, vegetables did grow better in soil that had first been loosened and to which manures were added. This had nothing to do with tiny particles of soil; it was because breaking up the soil supports Rule #2. Breaking up forest soil in order to plant a garden actually does more than make a treeless field; it reverses the results of years and years of succession, destroying the network of fungi in the soil. With fewer fungi, soils become bacterially dominant, a boon to nitrate-loving vegetables and row crops. The addition of manures by these early American farmers also greatly increased bacterial populations, as these are great bacterial food.

So, in the short term, breaking up America's virgin forest soils and mixing in manure made soils suitable for agriculture; however, rototilling or otherwise turning soil also destroys soil structure and displaces soil biota, disrupting the

soil food web. It completely chops up the miles of fungal hyphae that exist even in bacterially dominated soils. Worm tunnels and the pores between soil particles are all blown apart. Sure, the soil is fluffy after rototilling, but that's a dog's name, not a soil description. The first time water hits disturbed soil, it begins to compact, a spiraling, downward course that continues every time it rains or the bed is watered.

Even bacterially dominated soils need to contain some fungi to maintain soil structure and microbial diversity. Soil food web gardening practice requires that the soil be disturbed as little as possible when it comes to annual and vegetable gardens, unless you are trying to establish a vegetable or annual garden in fungally dominated soils. Use a trowel, dowel, or dibble to make discrete holes for plants or seed. You can also lightly pull a hoe or the corner of a 2-by-4 board along a row and plant in the limited disturbed wake, backfilling with good bacterially dominated compost. You will get fewer weeds using this method because you are not opening up the soils and exposing weed seeds to the light that is required for germination.

## Soil food web workers are great farmers

How do you encourage the bacterial domination needed for your annuals, vegetables, and row crops if you cannot rototill? Like everything in the soil food web, if you feed them, they shall come. Green mulches promote bacteria. In this case, not only does green mulch provide nutrients for the proper and necessary soil food web organisms, it also prevents weeds from germinating and holds moisture in, preventing it from evaporating. Too, bacteria like the easy-to-digest stuff, so the finer the green mulch, the higher the bacterial growth. Since soil bacteria also favor dampness, wetter mulches—to a point—will also promote bacteria. There is a fine line between damp, aerobic mulch and wet mulch that fosters anaerobic conditions, however, so be careful. Use your nose as the tester. If there is a bad smell, you put in too much water and need to aerate the mulch and back off a bit on the water.

In addition to bacteria-supporting mulch, your soils should have plenty of good organics to feed the microbes that are feeding your plants. Use any organic microbe food—with all three of the NPK numbers below 10—to ensure that fragile fungi are not killed. You can put these in the root zone when you plant, or side-dress before you mulch and then add as needed. Apply bacterially dominated teas as both a soil drench and foliar spray to prevent or control diseases and to keep microbial populations in the soil at high numbers.

Lawn clippings are a terrific green mulch to use around your annual flow-

ers and your vegetables during the growing season. Even though they lose their color and turn "brown," they are still considered "green" mulch because when they were cut, they contained sugars that remain even after the chlorophyll has faded. The same is true of straw. And it is still a good idea to add organics to garden soils in autumn so they have a chance to start to break down before spring planting. Try alfalfa meal, straw, or grass clippings—all good bacteria food. The bacteria get started in autumn; during this season, they can combine all the nitrogen they need with available carbon, without interfering with any plant's needs. Nitrogen tie-up at the soil-mulch interface, if it occurs at all, will be over by spring.

When it comes to growing plants that require nitrates, good populations of protozoa and nematodes are part of the equation as well, as they are the cycling mechanism. Apply protozoa soup as a soil drench to help increase nutrient recycling in your vegetable and flower gardens. It may take a week or so for the protozoa to find the bacteria in the rhizosphere, so wash down any application of bacterial food with an immediate dose of protozoa soup. Commercial nematode products have hit the home horticultural market, but these are usually specific for garden pests such as slugs. Your best bet for increasing the populations of nutrient-cycling nematodes—and by far the most economical—is still good compost and compost tea.

Vegetable garden with straw mulch on the beds. Courtesy National Garden Bureau.

And, of course, you will have the benefit of mycorrhizal fungi working in your gardens if you follow soil food web practices. Mycorrhizae even help plants grown in containers. The longer the season, the bigger their role. This is because it takes time for these fungi to establish and grow. Rule #19 requires that soil food web gardeners always mix endomycorrhizal fungi with the seeds of annuals and vegetables at planting time or apply them to roots at transplanting time.

Of the plants that do not form mycorrhizae, many are vegetables. In particular, the families Brassicaceae (which includes cabbages, mustards, and

The potted marigolds on the right show the benefit of endomycorrhizal fungi. Courtesy Mycorrhizal Applications, www.mycorrhizae.com.

Root balls are considerably larger when corn plants (family Gramineae) are treated with endomycorrhizal fungi, as was the one shown here on the right. Courtesy Mycorrhizal Applications, www.mycorrhizae.com.

broccoli) and Chenopodiaceae (spinach, beets, lamb's-quarters) do not form mycorrhizal associations; using mycorrhizal products on these particular plants is a waste of time and money.

Once you stop applying chemicals, you will eventually find earthworms in your vegetable and flower gardens. An application of a few inches of bacterially dominated compost in early fall will help attract and support worms, as will a bacterially dominated compost tea as a soil drench. If you fail to attract earthworms, it is a sign that you need to increase bacteria and protozoa populations. Do so, and then add some worms to your annual and vegetable gardens if you want to speed things up. You can soil drench your plants once a week to once a month, depending on their performance.

## Weeds

All too often the reaction of the gardener to a weed in a flower or vegetable garden is to douse it with whatever herbicide is suggested and often a bit more than the directions call for, for good measure. For obvious reasons this is not sound soil food web practice. Applications of powerful nonselective herbicides harm the soil food community in much the way chemical fertilizers do, killing micro- and macroarthropods, as well as microbes. Instead, carefully hoe weeds up or use vinegar, heat, boiling water, corn gluten, and other weed-controlling methods that have fewer and more temporary consequences to the microbiology in the soil. Should you ever need to resort to an herbicide (and we sincerely hope you won't), you must take remedial action as soon as practicable (Rule #15 again). Let the poison take its toll and then take steps, using all three soil food web tools, to get the biology back where it belongs.

When it comes to preventing weeds in the first instance, nothing beats mulches. The nitrogen, phosphate, and sulfur weeds need to germinate and grow are tied up by the biology at the interface of the mulch and the soil. This makes it doubly hard for weeds to do well, as in addition to facing no light and a physical barrier to their growth, they are given a poor supply of nutrients. Really, when you think about it, why fuss around with the other tools, compost and compost teas? Put down 2 to 3 inches (5 to 7.5 centimeters) of a bacteria-supporting mulch before weeds appear, taking care to leave a bit of "bare" soil around the stems of your plants.

Other than the work it takes to apply mulch, soil food web gardeners need never worry about weeds again. Indeed, our experience has convinced us that returning the appropriate microbiology to your soils may be the only step you'll need to control many of your annual weeds, those that thrive on the high

concentrations of nitrates found in chemical fertilizers. Many of the plant pests we had in our gardens disappeared once we started working with the soil food web. Chickweed, our nemesis, completely vanished, as plants no longer got their fix of high nitrates and had trouble germinating in the first instance, their seeds buried under mulch and not exposed to light because we don't rototill.

High-nitrogen fertilizers encourage opportunistic annual weeds. Given an ample supply of nitrates, an unwanted plant suddenly has the food power to really take over. Adding to the injury, the mycorrhizal fungi your veggies and annuals use to help obtain water and nutrients, particularly phosphate, are killed. The host plant doesn't do as well; the surface-feeding, nitrate-loving weeds grow faster and overrun the garden, outcompeting the main crops for light.

Once you get the soil food web humming, any nitrates needed by plants will come from the natural course of cycling. Instead of being poured on in a concentrated, chemical form and killing off the soil food web, the only nitrates being used will be those produced by the soil food web itself. And—without chemicals and with a bit of inoculation—mycorrhizal fungi will return.

## "Pests"

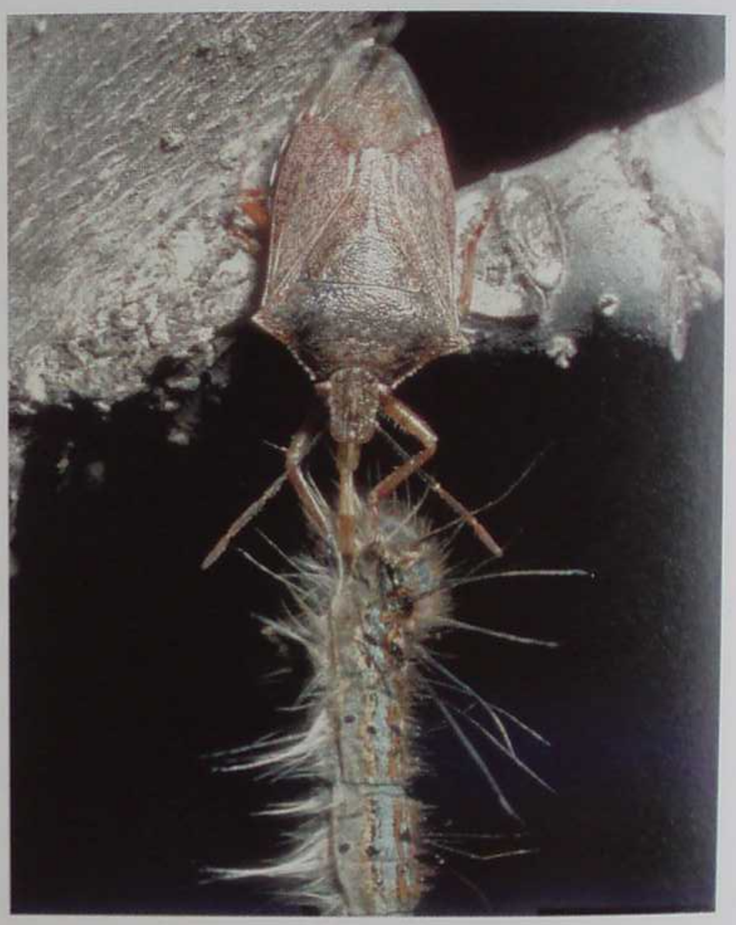
It is never an ideal world, unfortunately, but most insects (we use the term loosely to include spiders and others that are not truly insects) we encounter in our flower and vegetable gardens are helpful in lots of ways. Who needs to be reminded that insects pollinate flowers? Their larvae tunnel through soil and aerate it, and insects eat each other and participate in the recycling of plant nutrients. In most instances, insects get out of hand in your gardens because something is wrong with the soil food web, which normally maintains a bal-

A spined soldier bug makes a meal of the Mexican bean beetle larvae on this snap bean. Courtesy USDA-ARS.

ance between pests and predators. But you are not going to have a totally pest-free garden even with the soil food web in place. Accept it as part of the science. If your soil food web is healthy, this community will help plants overcome any insect pest. If there are a few bad guys, you need to realize that these help maintain the good-guy populations.

Every gardener has access to local agencies that will provide assistance in distinguishing beneficials from pests: learning about the beneficials in your area is part of learning to garden with the soil food web. Ladybird beetles and

A ladybird beetle larva devours aphids. Courtesy Clemson University, USDA Cooperative Extension Slide Series, www.forestryimages.org.



A stink bug does in an eastern tent caterpillar. Photograph by Robert L. Anderson, USDA Forest Service, www.forestryimages.org.

Braconid wasp larvae parasitize a hornworm. Courtesy R. J. Reynolds Tobacco Company, R. J. Reynolds Tobacco Company Slide Set, www.forestryimages.org.

their larvae feed on aphids, scale, and spider mites. Ground beetles eat cutworms, root maggots, slugs, and snails. Rove beetles eat fly maggots and eggs, aphids, mites, slugs, snails, and nematodes. Assassin bugs are adept at getting flies, mosquitoes, and caterpillars. Green lacewings and larvae gobble up aphids, spider mites, whiteflies, and caterpillars. Hornets take out flies. The soil food web gardener observes and learns what relationships exists—and fosters the good ones.

We don't like the use of pesticides in flower and vegetable gardens any more than we like the use of herbicides. These very nonselective substances have a flagrantly negative impact on soil food webs (again, Rule #15 will see that you rejuvenate the microbial universe in the soil and break down the residues of your action, if you have to use a pesticide). However, don't forget the lesser evils—insecticidal soaps, botanical insecticides, *Bacillus thuringiensis* (Bt)—all of which have varying impacts on the soil food web, but usually none as damaging as chemical insecticides.

## Schedule for restoration and maintenance

If you habitually used chemical fertilizers in your vegetable and flower gardens, you will need all three soil food web tools. Apply 1 to 2 inches (2.5 to 5 centimeters) of bacterially dominated compost before you plant annuals and veg-

Applying compost to flower and vegetable beds. Photograph by Judith Hoersting.

etables. Spray seeds with bacterially dominated compost tea and treat them and any seedlings with mycorrhizae right before you plant them. After you plant, lay down green mulch. Start weekly applications of bacterially dominated compost tea. These measures will restore or maintain the soil food web organisms in your vegetable beds.

Spray your vegetables with a bacterially dominated compost tea as soon as the first leaves appear and at least one more time a few weeks before harvest. Spray a third application on the debris left over from the growing season.

Avoid compaction; try to stay out of the garden beds, and limit and direct pathways through them. Side-dress and top-dress plants with compost whenever possible, and put compost on garden beds before the winter. As long as it is bacterially dominated, you cannot apply too much.

Finally, it is important to mulch garden beds in autumn so that the bacteria, fungi, protozoa, and nematodes can work during the winter to cycle nutrients.

Restore and maintain the soil food webs in your flower and vegetable gardens. If we are not mistaken, the great size and taste of organically grown produce will only match the particularly lovely glow of annuals raised using the soil food web.

Chapter 21

# A Simple Soil Food Web Garden Calendar

THERE IS NO ONE WAY to garden with the soil food web. Each garden is different, and so are the various soil food webs in them. Climate, too, plays a big part in when and even how you apply soil food web science. When it is very cold, compost teas are definitely not going to work, and colder temperatures freeze up compost and mulch. Times of drought might not be the best time to apply compost tea, and putting down mulch at the wrong time in a drought situation could prevent the soil underneath from absorbing water.

Still, no matter where you garden, you should at least consider the microbes and other animals in your soil food webs as each season rolls by. Yard and garden care is no longer just about plants. You have to pay attention to the microbes if you are going to team with them.

## Spring

Spring is when you first check things out and give your soils a microbiological boost. The compost pile should be cranked up so you'll have ample supply of compost throughout the growing season. Turn last fall's pile, and if you have room, start a new pile designed to be fungally dominated. Use the organic debris that accumulated during the winter and some of last fall's leaves. Use the first grass clippings to get good bacterial compost going as well.

Mulches should be pulled back to let soil warm up if necessary and then put back and supplemented. Use compost teas on seedlings both as a soil drench and a foliar spray. Inoculate all seeds and transplants with the appropriate kind of mycorrhizal fungi.

Three weeks before leaves appear, have your soils and tea tested for their microbiology. You don't have to do this every year, but you surely should the first year or two of gardening with the soil food web. Thereafter, your plants will let you know how you are doing. You might want to have your compost piles tested as well. This is also the time to test things yourself, using Berlese funnel soil traps and your own eyes. You want to be able to correct any gaps in your soil food webs before you plant.

Two weeks before leaf-out, aerate your lawns. Again this doesn't have to be done every year, but it is definitely a consideration the first year after you stop using chemical fertilizers. Thereafter, you only need to aerate in the early spring every three or four years, depending on the amount of traffic your yard receives; the amount of ice that accumulates each winter, if any; and the state of the soil food web as evidenced by worm, mite, and mushroom activity.

After aeration (or two weeks before leaf-out of trees and shrubs, if you didn't aerate), apply an appropriate organic microbe food, such as soybean meal, to lawns. If you experienced too many mushrooms (or mushrooms of only one species) the previous year, apply some alfalfa meal instead, as it will feed more bacteria than fungi.

This is also the right time to spray lawns with a slightly bacterial or balanced compost tea, at the rate of at least five gallons of tea per acre. Paths in the lawn created by winter traffic should be cordoned off and sprayed with a fungally dominated compost tea to restore structure. When you finish making teas, throw the leftover compost and any excess on these paths. After a few applications, things will be downright spongy. Even without tea, make sure the organic microbe food in these areas is sufficient to support existing microbial populations. You can't burn the lawn applying these organics, so don't worry.

Tidy up the brown mulch layer under trees and shrubs and around perennials and refresh it if you need to. This is why you should save leaves in the autumn when they drop: they can be hard to come by in the spring. If you don't have leaves, bark chips will do. You can spread compost at this time and cover it with mulch to control weeds. Apply a fungal food (humic and fulvic acids, cold-water kelps, phosphate rock dusts) to your plants, and then give each tree, perennial, and shrub a soil drench of your most fungal compost tea. Spray a fungal tea on your perennials at least once after their leaves appear.

Treat any seeds or transplants with the appropriate mycorrhizal fungi first. If possible soak transplants in aerated compost tea before planting. Spray compost tea on seeds before planting, and apply a soil drench after germination.

Neither till the vegetable garden nor turn over the soil in the annual beds. Apply 4 lbs per 100 square feet soybean meal as soon as you can after the soils thaw, and spray with a bacterially dominated tea. When planting, drill holes for seeds or disturb just the row where they will be planted. Use lots of green mulch after the soil warms up.

## Summer

During the summer months you need to continue with the spray and drench program started in the spring, especially the first year after you stop using chemicals.

Microbial activity should be taking care of lawn clippings. If they are accumulating at a noticeable rate, or the lawn is not greening up enough and lack of water is not the cause, spray or sprinkle on a protozoa soup. A second application of soybean meal or other microbe food is in order. It is useful to do more Berlese funnel tests to see what is going on. Keep records for later comparisons.

Liberal applications of bacterially dominated compost and frequent replenishment of green mulches will keep weeds down in vegetable and annual gardens. Apply microbe food once every two weeks if needed.

Fungal compost and mulch should be applied liberally around trees, shrubs, and perennials. Mix in any twigs or sticks these plants drop. You might run these over with a lawn mower, in place, just to open them up a bit and make them look neater.

Any plants showing signs of disease or stress should be immediately sprayed with compost tea followed by a soil drench of tea.

## Autumn

Just before the tree leaves start to drop, gather up a load of grass clippings for fall composting, which should begin while the grass is still fresh and green. You can also put some of this green mulch on annual and vegetable beds, even if the season is coming to an end. Use mycorrhizal fungi on the roots of any autumn transplants.

Turn leaves that fall on lawns into a fine mulch with your mower (you may have to run over them more than once). Leave them in place. This will provide some fungal balance to the bacterially dominated teas you have been applying to the lawn. Gather the rest of the leaves, every single one you can. Brown leaves are always in short supply when it comes to spring and summer composting. Build your compost pile and store the rest.

Mulch vegetable and flower garden beds. After leaf drop, make sure all your shrubs, trees, and perennial plants are properly mulched, too, and if possible, use fungally dominated compost first.

In the first year of using the soil food web, spray 20 gallons of tea per acre, making sure to inoculate mulches and leaves. Microbial action should decay

about half the leaf mass within a month or so if it is warm (and by the end of spring, even if it is cool).

Apply a good organic microbial food of the appropriate type. Let the microbes go to sleep with full stomachs, wake up early, and start cycling nutrients.

After harvests, have your soils tested again and make some Berlese funnel runs, if it is not too cold; compare these tests to those you took in the spring and summer. This will allow you to manage your soils during the winter months so they are ready come next spring.

## Winter

Spend winter reading up on the soil food web, surfing the Internet and browsing libraries with that subject in mind. This is a new science, and its applications to the home gardener are ever expanding. New products, such as specialized predatory bacteria and nematodes that take out pests and pathogens, are being introduced all the time. All sorts of new compost tea makers, sprayers, and nutrient ingredients are hitting the market. There is a lot out there to help you team with microbes, and you need to keep abreast of the latest developments.

Of course, just because it's winter doesn't mean you should stop using compost teas. You can have an abbreviated soil food web system working for your indoor plants; make sure the potting soils contain ample organic foods to support the microbial life you are adding.

Finally, depending on where you live, your compost pile may still be workable in the winter. Give it a few turns. You know the saying: a few good turns will make you a better gardener.

Chapter 22

# No One Ever Fertilized an Old Growth Forest

DOES THE SOIL FOOD WEB really support plants? Will it work in your yard and gardens? Just to give you confidence and to encourage you to use what you have learned, we point you in the direction of the nearest forest. Or simply close your eyes and visualize any wooded area you remember visiting. You can almost hear a stream nearby, the wind running through the leaves. It is beautiful, majestic—and no one ever fertilized any of the plants there. Not one single time. How can this be? You know the answer. The beautiful plants in these beautiful areas are completely controlled by the soil food webs in which they live.

It often comes as a surprise when gardeners so reflect. Only then does the full force of the realization hit: every single plant you are seeing produces exudates and attracts microbiology to its rhizosphere. This community in turn attracts micro- and macroarthropods, worms, mollusks, and the rest of a complete soil food web. It is a natural system, and it operates just fine without interference from man-made fertilizers, herbicides, and pesticides. Tall oaks grow from small acorns with no blue powders to feed them or nasty smelling sprays to protect them. Plants flourish nonetheless, thanks to bacteria, fungi, protozoa, nematodes, and the rest of the soil food web gang.

We know it is possible to let the very same kind of soil food webs take over in your yard. Long before construction, traffic, rototilling, the application of fertilizers and other chemicals, a healthy soil food web existed there. You can return it. You can even improve it. Once you work with the microbes at the base of the soil food web, you will reestablish that soil food web. We know. We and thousands of our neighbors and friends have done it.

You have been introduced to the basic science of soil food webs. You know how the system works, and you have been exposed to its benefits. With the microbiology returned to your yard, soil structure improves. Mycorrhizal fungi will help your lawn, trees, shrubs, perennials, annuals, and veggies get the nutrients they need. Pathogens face fierce competition. Plants get more of the kind of nitrogen they prefer. Water drainage and retention are improved. Pollutants are decayed. Food tastes better. Flowers look better. Trees are less

stressed. And you don't have to work so hard; you will have lots of helpers. Best of all, you won't have to worry about the affects of chemicals on you or your family, pets, or friends.

Remember: no one ever fertilized an old growth forest. They didn't have to. You have been given the rules to garden using the soil food web. There are not many of them. What are you waiting for? Start teaming with microbes and get that biology into your soils and working for you. Gardening with the soil food web is the natural way to grow.

No one fertilized this forest. Photograph by Judith Hoersting.

Appendix

# The Soil Food Web Gardening Rules

1. Some plants prefer soils dominated by fungi; others prefer soils dominated by bacteria.
2. Most vegetables, annuals, and grasses prefer their nitrogen in nitrate form and do best in bacterially dominated soils.
3. Most trees, shrubs, and perennials prefer their nitrogen in ammonium form and do best in fungally dominated soils.
4. Compost can be used to inoculate beneficial microbes and life into soils around your yard and introduce, maintain, or alter the soil food web in a particular area.
5. Adding compost and its soil food web to the surface of the soil will inoculate the soil with the same soil food web.
6. Aged, brown organic materials support fungi; fresh, green organic materials support bacteria.
7. Mulch laid on the surface tends to support fungi; mulch worked into the soil tends to support bacteria.
8. If you wet and grind mulch thoroughly, it speeds up bacterial colonization.
9. Coarse, dryer mulches support fungal activity.
10. Sugars help bacteria multiply and grow; kelp, humic and fulvic acids, and phosphate rock dusts help fungi grow.
11. By choosing the compost you begin with and what nutrients you add to it, you can make teas that are heavily fungal, bacterially dominated, or balanced.
12. Compost teas are very sensitive to chlorine and preservatives in the brewing water and ingredients.

13. Applications of synthetic fertilizers kill off most or all of the soil food web microbes.
14. Stay away from additives that have high NPK numbers.
15. Follow any chemical spraying or soil drenching with an application of compost tea.
16. Most conifers and hardwood trees (birch, oak, beech, hickory) form mycorrhizae with ectomycorrhizal fungi.
17. Most vegetables, annuals, grasses, shrubs, softwood trees, and perennials form mycorrhizae with endomycorrhizal fungi.
18. Rototilling and excessive soil disturbance destroy or severely damage the soil food web.
19. Always mix endomycorrhizal fungi with the seeds of annuals and vegetables at planting time or apply them to roots at transplanting time.

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## Compost tea brewers

Alaska Bountea / Alaska Bounty, Box 1072, Palmer, AK 99645, 907.745.8234, order@alaskagiant.com, http://www.alaskagiant.com/

Bob's Brewers, 6515 W. Marginal Way SW, Seattle, WA 98106, 206.767.7816, bob@bobsbrewers.com, http://www.bobsbrewers.com/

Keep It Simple (KIS), Inc., 2323 180th Ave. NE, Redmond, WA 98052-2212, 866.558.0990, kis@simplici-tea.com, www.simplici-tea.com, www.kisbrewer.com

Soil Soup, 305 9th Ave. N, Seattle, WA 98109, 877.711.7687, www.soilsoup.com

## Labs that perform biological testing

AgriEnergy Resources, 21417 1950 E. St., Princeton, IL 61356, 818.872.1190, info@agrienergy.net, http://www.agrienergy.net/.

BBC Laboratories, Inc., 1217 N. Stadem Dr., Tempe, AZ 85281, 480.967.5931, bbclabs@aol.com, http://bbclabs.com/.

Soil Food Web, Inc., 980 NW Circle Blvd., Corvallis, OR 97330, 541.752.5066, sfi@soilfoodweb.com, http://www.soilfoodweb.com.

## Mycorrhizal fungi

Mycorrhizal Applications, Inc., Box 1181, Grants Pass, OR 97528, 866.476.7800, http://www.mycorrhizae.com/index.php?cid=60.

T and J Enterprises, Thomas Giannou, 2328 W. Providence Ave., Spokane, WA 99205, 509.327.7670, http://www.tandjenterprises.com/.

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Jeff Lowenfels is a member of the Garden Writers of America Hall of Fame and has been writing a weekly column for the *Anchorage Daily News* since 1977. A native New Yorker, he now works as an attorney in Alaska and is a leading proponent of gardening using the concepts of the soil food web.

Wayne Lewis is a lifelong Alaskan gardener. He has worked with Jeff on many projects over the past 20 years, including the now national Plant a Row for the Hungry program (started in Anchorage by Jeff), which encourages gardeners to donate a portion of their harvest to charitable organizations in their community.

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