Chapter 4

Science of Composting

Objectives

1. Understand the magic - how we go from colorful inputs to dark crumbly material Define the inorganic and organic components of soil.
2. Understand the important contributions humus makes to soil.
3. Understand how the Soil Food Web provides plant nutrients.

<u>Terms Defined in this Chapter</u>:

Ammonium
Compost tea: aerated, non-aerated
Denitrifying bacteria
Finished Compost
Humus
Loam
Macronutrient
Micronutrient
Nitrifying bacteria
Nitrogen Cycle
Petroleum-based fertilizer
pH
Pore
Soil aggregate
Soil amendment
Soil Food Web
Soil texture
Tilth

Compost Biology 101

Biologic decomposition is primarily the work of thousands of microscopic species of bacteria, fungi and a special group of organisms related to fungi called ***actinomycetes***. Microorganisms that feed on dead organic material are called ***saprophytes***. The ***saprophytic microbes*** can be divided into two basic groups, ***aerobes*** and ***anaerobes***.

Aerobes require oxygen to live. Aerobic, saprophytic bacteria, fungi and actinomycetes rapidly degrade organic matter and give off heat, water and carbon dioxide as by-products. Aerobic decomposition is odorless, therefore yard waste and vermicomposting systems are designed to encourage aerobic organisms.

Anaerobes do NOT require oxygen to live, in fact, oxygen is toxic to them. Anaerobic organisms are found in nature on swamp bottoms and in other oxygen-poor environments. They work slowly, produce no heat, and give off methane (sewer gas), hydrogen sulfide (rotten egg aroma), alcohols, phenols, terpines, putresines and cadaverines (their names suggest their offensive smells). Many of the byproducts of anaerobes are toxic to earthworms, insects and plants. Anaerobes begin to function when oxygen concentrations drop below about 15%. When oxygen levels drop below approximately 8%, distinctive odors are generated.

Decomposition can occur by two basic processes, ***aerobic*** and ***anaerobic.***

- ***Aerobic decomposition*** requires oxygen.
- ***Anaerobic decomposition*** occurs in the absence of oxygen.

Because aerobic organisms give off heat as a by-product of degradation, ***an aerobic yard waste compost pile gets hot during the most active phase of aerobic activity***. The internal temperature of an active compost pile can reach over 160ºF. ***This heat is totally independent of outside weather conditions and is solely the result of microbial activity***. No one species of bacteria, fungi or actinomycetes can survive this wide temperature range. Rather, each species is best adapted to a relatively narrow temperature range. Scientists classify species into three broad groups:

- ***Psychrophiles***: Microorganisms that prefer temperatures ranging from 0ºF to 55ºF.

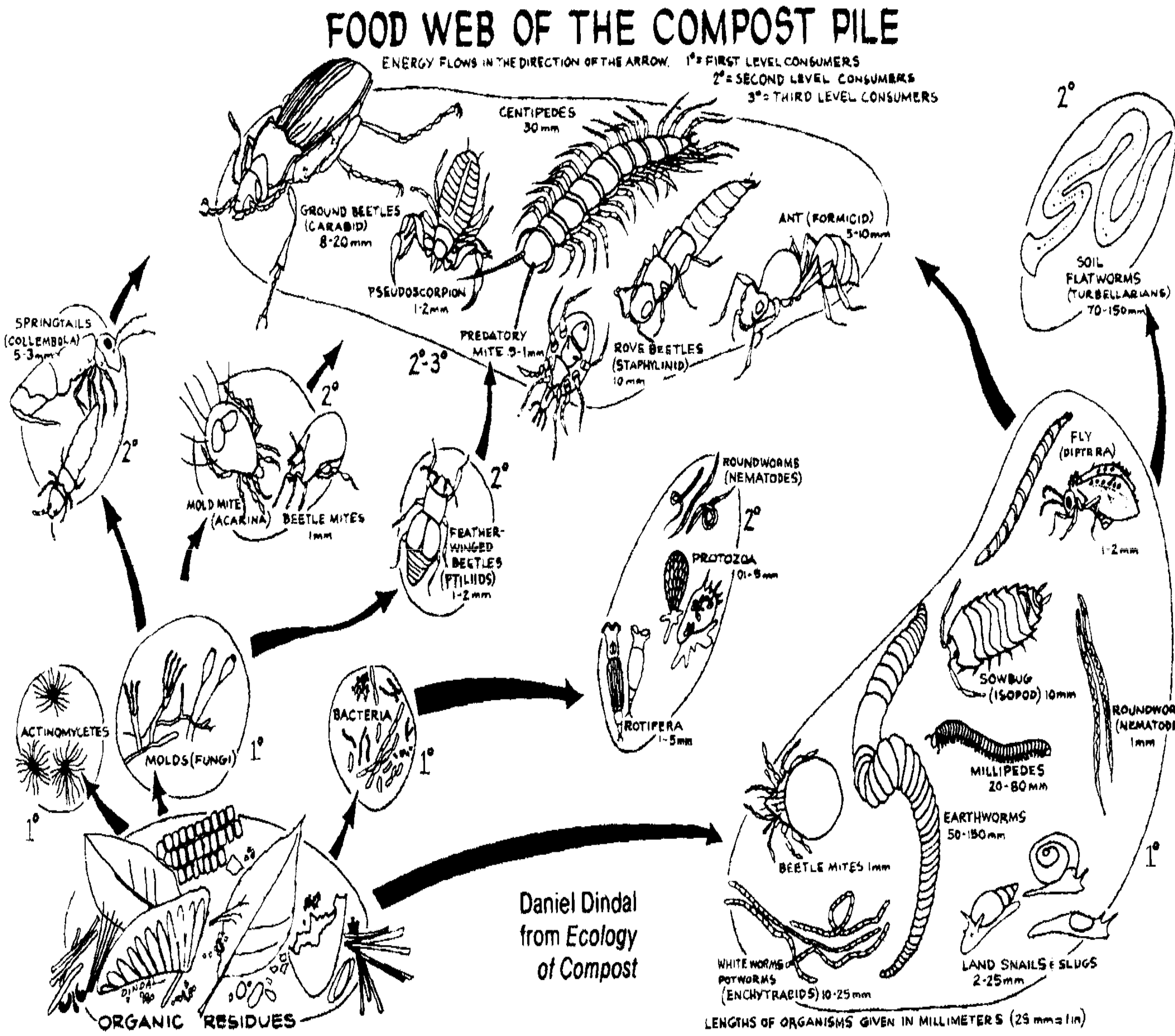
- ***Mesophiles:*** The optimal range for many mesophiles is 90ºF to 115ºF.
    - Actinomycetes and most fungi are mesophiles.

- ***Thermophiles:*** Microorganisms adapted to temperatures ranging from 110ºF to 160ºF. Temperatures above 160ºF kill even the thermophiles and effectively sterilize the compost pile.

Home compost systems are designed to encourage species from all three groups to be present at all times in a compost pile, ready to take advantage of whatever environment they encounter. Bacteria reproduce very rapidly; many have doubling times of 20 minutes or less. Under optimal conditions, in one hour, 100 microbes divide to become 200, then 400, then 800, etc. Because every individual in this huge population gives off heat as it decomposes organic wastes, the pile gets hotter and hotter. The psychrophiles are replaced by the mesophiles who are replaced by the thermophiles. The microbes that die contribute organic matter to the compost pile. Spores (seed-like reproductive bodies) generally survive high temperatures and will give rise to new individuals when the temperature cools sufficiently.

Microscopic bacteria, fungi and actinomycetes are the real workers in the compost pile, but they are just one part of a complex and fascinating ecosystem we call the "Compost Food Web" (see Figure 2-1*)*.

Figure 2-1. Compost Food Web. From Dindal 1971, *Ecology of Compost*.



Primary layer:

Bacteria, fungi and actinomycetes are at the bottom or primary layer (1^o) of the Compost Food Web. These organisms feed directly on decomposing waste. Thousands of species of these organisms exist, and it is not fully understood which species are most active in the compost process. Nonetheless, they all feed on decaying organic matter by secreting ***enzymes***. Enzymes are specialized proteins that break down carbohydrates, proteins or fats into simple molecules that can be used by the microorganism. These simple food molecules are then digested by the bacteria and fungi and utilized for building and maintaining cell structure, reproduction and energy. The byproducts of this metabolic process are carbon dioxide (CO_2), water (H_2O), and heat. Bacteria do the lion's share of work in a compost pile. They are the primary degraders of organic waste. There are species of aerobic bacteria that thrive in all temperature ranges. Actinomycetes and most fungi are mesophilic. They generally appear on the outside layer of the pile as a gray or green powdery coating. Both actinomycetes and fungi are most active in degrading ***cellulose*** and ***lignins***, components of paper and woody materials (ref. Goldstein, ed. *Biocycle Guide to the Art & Science of Composting*, p.18).

Flies, sowbugs, pot worms, ***earthworms*** and ***snails*** can also feed directly on wastes, but unlike the microbes, they produce a “manure” that can be further metabolized. In addition, some also feed on bacteria, fungi and actinomycetes, thereby acting as both 1^o and 2^o consumers. Earthworms are sensitive to light, temperature and moisture and will only visit a compost pile that is dark, cool and moist. Although they play a role in backyard composting, they are not usually present in large numbers. Vermicomposting is controlled in such a way to encourage earthworms and discourage thermophillic bacteria. Vermicomposting systems do not go through a thermophillic stage (see Chapter 3).

Secondary layer:

Bacteria, fungi and actinomycetes have enemies lurking in the compost pile. They are fed upon by a group of organisms that comprise the second layer (2^o) of the food web. These organisms include:

Protozoa: Microscopic single cell organisms capable of self-propelled movement that feed on bacteria. Protozoa help regulate bacterial populations and serve as a food source for organisms higher in the food web.

Nematodes or Roundworms*:* Microscopic, unsegmented worms with a long cylinder-shaped body. They feed on plants, bacteria, fungi and other nematodes.

Rotifers*:* Single cell organisms, usually found in water that move using rings of tiny hairs on its front end and feed on bacteria.

Springtails **(Colembola)**: Tiny, white insects that feed on fungi.

Mites **(Acarina):** Arachnid (8 legged, spider-like) insects that feed on fungi.

Beetles: Large group of insects that feed on fungi.

Black Soldier Fly Larva: Black soldier fly larva are voracious decomposers. Don’t be fooled, many see these “maggots” in their compost and get concerned, but these larva are actually a sign of a healthy pile. Larva typically appear in piles that have relatively high moisture, so one way to control them is by adding dry carbon material. When flies hatch, they typically live for only a few days. They are not aggressive nor annoying, and have no mouth parts with which to eat or bite. More info on this fascinating and beneficial creature can be found here: http://tinyurl.com/p7guwu.


Adult


Larva

Tertiary or Top layer:

The predators occupy the third and highest level of the Compost Food Web. These include:

Ground Beetles: Fairly large, feed on insects.

Pseudoscorpions: Rarely seen predator that feeds on insects.

Centipedes (Chilopoda): Fast moving, many legged predators that can bite humans and will eat beneficial worms. Not a welcome member of the compost pile.

Millipedes (Diploda): Round, hard-shelled, slow moving, many-legged beneficial vegetarian.

Ants: Many species, feed on insects.

All the organisms in the Compost Food Web are necessary to completely degrade organic waste and produce finished compost. In nature, the process of decomposition is erratic, depending on temperature, moisture levels and the types of decaying materials. Unlike natural decomposition, compost is biologically decomposed under controlled conditions, and ***well-managed yard waste composting favors aerobic microorganisms***. It is our job as composters to create and maintain an environment that encourages these organisms to thrive 24 hours a day. The **Five Control Factors**, described in detail below, are the keys to optimal performance.

What is soil?

To understand the importance of compost, you must understand soil. "***Soil is a mass of materials with pore space, air, and water that permit plant growth***" (ref. Miller, *Soils in our Environment,* p.18). The definition is deliberately broad because soils around the world are incredibly diverse. Soil is basically a complex combination of rock, gravel, sand, silts, clay, soluble minerals and decayed organic material. Soil formation is a slow, continual process. It begins as solid rock weathers and breaks into smaller pieces. Chemical reactions on these smaller rocks, stones and gravel release crystalline minerals. Decaying plants and animals supply organic humus to the mix. Eventually, the rock particles, minerals and humus accumulate enough to form soil. Under ideal conditions, recognizable soil "may develop within 200 years; under less favorable conditions, the time may be extended to several thousand years" (ref. Miller, *Soils in Our Environment*, p.23).

Sand, Silt and Clay

The inorganic component of soil is made up of particles derived from solid rock. These particles range in size from clay (the smallest) to sand (the largest).

Sand: Most ***sand*** is derived from the mineral quartz (silicon dioxide, SiO_2). Individual sand particles range in size from 0.05mm-2mm in diameter. Individual sand particles can be seen by the naked eye and sand feels gritty to the touch. Because of its large particle size, sand drains very quickly. It cannot trap water to feed plant roots. In addition, sand alone contributes virtually no plant nutrients to the soil; silicon dioxide is essentially inert. In soil, sand particles help form open pores for air and water.

Silt: Chemically, ***silt*** is very similar to sand, but its particles range in size from 0.002mm-0.05mm diameter and can be seen under a microscope. Like sand, silt is nutritionally insignificant.

Clay: Unlike sand and silt, ***clay*** is not simply a tiny chip off the old quartz rock. Clay is made up primarily of silicon, aluminum and oxygen. Clays are "newly formed crystals, re-formed from the soluble products of primary minerals" (ref. Miller, *Soils in our Environment*, p.128). In other words, the soluble fraction of various primary minerals undergoes drastic chemical changes that ultimately lead to the formation of clay crystals. Many specific clay types exist, but all clay particles are less than 0.002mm in diameter. They can only be seen with an electron microscope.

Because of its small pore size, clay has exceptionally high water retention properties. ***Clay also has a negative charge that attracts and holds positively charged ions important to plant nutrition and to the pH (acid-base balance) of the soil***. ***pH*** is a measure of the relative acidity of a compound. The ***pH scale*** ranges from 0 (most acidic) to 14 (most basic). A pH of 7 is neutral.

Believe it or not, ***clay is the base for all good soils***; so the clay in our Clark County soils is not entirely a bad thing! We will talk later about how compost can amend a clay soil. Clay crystals form sticky, lattice-like plate structures, which act, with ***humus***, as cement to bind sand and silt into stable ***soil aggregates.*** The composition of these aggregates determines ***soil texture.***

"***Soil texture***" is the degree of fineness or coarseness of the soil, which is an expression of the percentage of the relative amounts of sand, silt and clay" (ref. Harpstead, *Soil Sci. Simp*., p.23). Table 9 shows the composition of various soil textures. Soils in Clark County tend to be high in clay. ***Loam*** is considered the ideal soil type.

Table 9. Soil Texture. (Adapted from Miller, *Soils in Our Environment*. p.98)

Soil Texture	% Sand	% Silt	% Clay
Clay	20	20	60
Silt Loam	20	70	10
Sandy Loam	65	25	10
Loam	40	40	20

Sand + Silt + Clay + Humus = Soil

Pure sand, silt and clay are not considered soils because alone they cannot support plant life. Sand, silt and clay form the textural framework or skeleton of soil. Organic matter provides the "body" and plant-sustaining nutrients. In nature, organic matter is slowly broken down by a variety of organisms until it is finally incorporated into humus. Humus then binds sand, silt and clay to form soil. Although the organic substances remaining in humus continue to decompose slowly, humus is *very* stable. In fact, studies with radioactive carbon show that much of the humus in present-day North American soils is derived from plants that died before European colonization (ref. Stevenson, *Humus Chemistry*, p.13).

What is Humus?

In nature, stable, decomposed organic materials are called humus.

How is humus formed?

Humus is basically the end product of organic decomposition. The conversion of organic matter to humus is a slow process of physical and chemical transformation. The easiest way to envision the process of humus formation is to divide the soil into pools or fractions. As organic matter passes from one fraction to the next, it becomes indistinguishable from the soil itself.

Litter fraction. When an organism dies, its body becomes part of the litter fraction. Litter is dead organic matter that lies on the soil surface. When organisms die, their cells rupture and release sugars, starches, complex carbohydrates, proteins and fats. Litter provides a rich diet to soil bacteria, fungi and other microorganisms as well as to earthworms and insects. As they consume the fresh organic litter, these soil dwelling organisms pull the nutrients into the top layer of soil called the light fraction.

Light fraction. The light fraction of the soil consists of "residues in varying stages of decomposition that exists within the soil proper" (ref. Stevenson, Humus Chemistry, p.2). Materials in the light fraction are constantly changing; they provide food for soil organisms, which then provide nutrients for plants. Decomposition in the light fraction can occur quickly or slowly and the rate depends on many variables.

Stable humus fraction. When soil organisms have depleted the easily digestible components of decaying organic matter, some materials, particularly the complex proteins, complex sugars and woody lignins, remain resistant to decomposition. These resistant materials undergo an extremely complex series of biochemical reactions that ultimately converts them to humus (ref. Stevenson, Humus Chemistry, p.210). Humus then combines with clay, sand and silt to form soil.

It is important to keep in mind that when humans control the decomposition process by composting, they are simply "managing an ongoing natural process for their own convenience and utility" (ref. Putnam, Ortho Books: Easy Compost, p. 21). In other words, compost is basically man-made humus.

Humus is not easy to define. "All humus molecules are different from each other and are constantly changing as they are attacked by microbes and further decomposed." (ref. Miller, Soils in Our Environment, p.140). Humus is a diverse system of huge molecules; each made up of simple chemical building blocks that link together to form long looping chains. Each chain contributes unique chemical properties to the humus molecule that affect the physical, chemical and biological properties of the soil. One could think of humus as a vast microscopic octopus, each arm of which has multiple sites to bind clay, hold water, trap oxygen, house microorganisms and capture plant nutrients. As you will learn, humus is truly as complex as the life it supports.

Humus, Plant Growth and the Physical Properties of Soil

Humus affects many of the physical aspects of soil that directly contribute to plant growth. In fact, even the dark, rich color of soil is due to humus. One of the most important contributions humus makes is in altering soil texture and improving ***tilth***. Well-aggregated soil is loose and easy to till, in other words, it is said to have ***good tilth***. Humus is vital to forming good tilth in every soil type. As you learned, clay and humus act together to form soil aggregates. ***The degree of soil aggregation is directly related to plant growth because well-aggregated soil is full of pores***. Pores are simply open spaces between particles within an aggregate and between adjacent aggregates. These pores allow oxygen and water to penetrate, roots to spread and shoots to sprout easily. In addition, well-aggregated soil is less likely to be washed away by moving water, and it supports abundant earthworms and other beneficial soil creatures. Humus-rich soil retains water and acts as a reservoir to plants. In fact, organic matter can hold up to 20 times its weight in water (ref. Stevenson, *Humus Chemistry*, p.15). In contrast, poorly aggregated soils have few pores and do not allow sufficient oxygen and water penetration. Seed germination and root growth suffer from oxygen deprivation and plant health suffers, even when plant nutrients are in good supply.

In addition to improving soil texture, the looping arms of a humus molecule act to bind important nutrient minerals and make them available to plant roots. Like clay, humus has a negative charge and can attract and bind positively charged minerals such as potassium (K^+), ammonium ($NH4^+$), sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), manganese (Mn^{2+}), copper (Cu^{2+}) and zinc (Zn^{2+}).

Humus also contributes to the pH (acid/base balance) of the soil by acting as a ***buffer***, absorbing excess acid or base and helping the soil maintain a favorable pH. Most soils typically have a pH between 4-8 (7 is neutral, above 7 more basic, below 7 more acidic). “Ideal” soil pH depends on what one wants to use the soil for (growing, building, nothing). The pH of soil is very important in making nutrients available. ***On a weight basis, humus has a nutrient binding capacity and buffering capacity far greater than clay*** (ref. Miller, *Soils in Our Environment*, p.140). When pH conditions are favorable, the positively charged nutrients bound to soil aggregates are released to plant roots. ***Together, clay and humus act as a repository for plant nutrients, preventing rainwater from leaching them away and slowly releasing them to hungry plant roots.*** But where do the plant nutrients come from? In unfertilized soil, decomposing organic matter and the organisms associated with it provide the soil with a pool of vital nutrients.

Humus, Plant Growth and the Soil Food Web

Decaying organic matter and humus is critical to plant growth. It is a common misconception that soil is an inert substance that passively supports plant roots. Nothing could be further from the truth. ***Soil is abundantly alive***. As dead organic matter is converted to humus, it feeds a living ecosystem teeming with diverse organisms. ***It is these organisms, not the organic matter itself, that bring life to soil***. Scientists estimate that one teaspoon of healthy soil contains 100 million to 1 billion bacteria, thousands of fungi and protozoa, hundreds of nematodes and insects and 10-50 earthworms (ref. Edwards, *Soil Biol. Primer*, p. B-2).

As soon as a plant or animal dies, it becomes food for thousands of species that make up the ***Soil (Compost) Food Web***, shown in Figure 9. As you will learn, the organisms involved in making soil are the same organisms we find in a compost pile or worm bin. These organisms include bacteria, fungi, actinomycetes, protozoa, nematodes, insects and earthworms. As soil organisms consume organic waste, they use nitrogen, carbon and other digested chemicals to build their cells. As species at the bottom of the food web die, they become food for those higher up. As nutrients move through the web, they are converted into many complex organic forms that ultimately form humus and soil. Plants are nourished when certain species of soil bacteria convert complex organic molecules back to the simple minerals plants require.

In addition to their important role in nutrient cycling, some organisms of the Soil Food Web protect plant roots from pathogens and still others can break down pesticides and pollutants (ref. Edwards, *Soil Biology Primer,* p. C-1). Larger organisms, like insects and earthworms, act as soil mixers and till organic matter deep into the soil.

Plant Nutrition

"Plants need at least 16 essential elements to grow. The 16 essential nutrients are carbon, oxygen, hydrogen, nitrogen, calcium, potassium, magnesium, phosphorus, sulfur, chlorine, iron, boron, manganese, zinc, copper and molybdenum" (ref. Miller, *Soils in our Environment,* p.261).

Hydrogen, oxygen, carbon, nitrogen, potassium and phosphorus are needed in the largest amounts and are considered ***macronutrients***. The other elements, needed in smaller amounts, are considered ***micronutrients***. Plants obtain hydrogen, oxygen and carbon from the air. They must obtain all the other macro and micronutrients from the soil and the "***principal soil storehouse for large amounts of nutrients is soil organic matter"*** (ref. Miller, *Soils in our Environment,* p.261). Unfortunately, many of the nutrients in that organic matter are present in a form that plants cannot use. Plants rely on the organisms of the Soil Food Web, particularly fungi and bacteria, to convert vital nutrients to a plant-friendly form.

Soil bacteria are primary decomposers of organic matter and the backbone of the Food Web. As a means of illustrating the vital connections between plants, soil, and the organisms of the Soil Food Web, we will focus our discussion on the ***Nitrogen Cycle***. Keep in mind that Food Web organisms are involved in converting many of the nutrients present in the soil to a plant-usable form and that ***similar cycles exist for other nutrients***.

Soil Bacteria and the Nitrogen Cycle

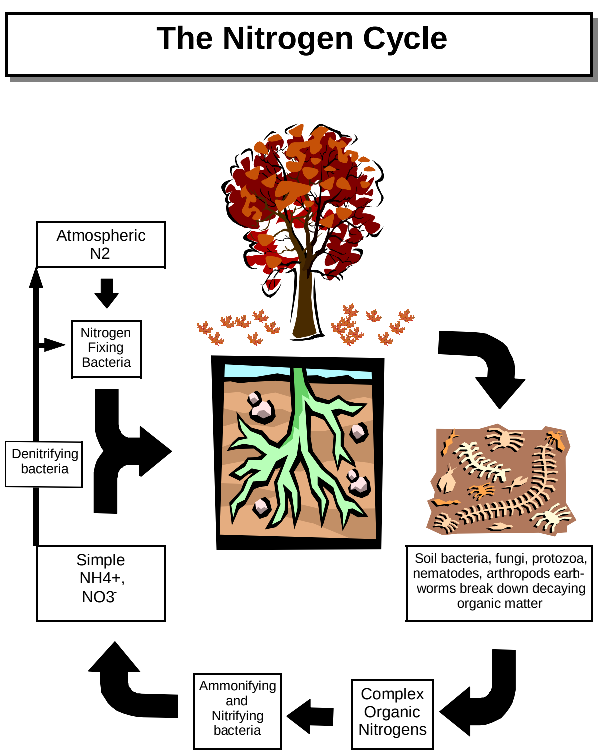
The most important macronutrient is nitrogen. All living organisms require nitrogen in a form they can use to build enzymes, structural proteins, and DNA. Plants derive their nitrogen from the atmosphere and the soil, and animals derive it from eating plants or other animals. Eventually, the nitrogen is returned to the atmosphere. This continual transformation of nitrogen from one form to another is called the ***Nitrogen Cycle.***

Although almost 80% of our atmosphere is made up of nitrogen, atmospheric nitrogen (**N_2**) cannot be used by plants or animals until it is converted to other forms. Atmospheric nitrogen is composed of two nitrogen atoms held together by a very strong chemical bond. Only certain bacteria, volcanic action and lightning can break that bond in nature. Synthetic chemical reactors require extremely high pressure to cleave nitrogen. Of the thousands of bacterial species that thrive in the organic component of the soil, one group, the ***nitrogen fixers***, actually live around or inside the roots of certain plants (mostly legumes) and convert atmospheric nitrogen into ***ammonium (NH_4^+)***, a form the plant can use.

Only certain plants can obtain their nitrogen from nitrogen fixing bacteria. Other plants rely on the ***ammonifying*** and ***nitrifying soil bacteria***. When the organisms of the Soil Food Web feed on organic plant and animal wastes containing nitrogen, they convert the nitrogen they consume into amino acids (the building blocks of proteins), proteins and other complex organic compounds that they need to grow and reproduce. They then excrete nitrogen containing "manures." Plants cannot use these organic nitrogens. They must rely on ammonifying and nitrifying soil bacteria to convert these organic nitrogen molecules into simple inorganic ammonium (NH_4^+) and nitrates (NO_3^-) that can be used by plants. Any ammonium that is not immediately used can bind the negatively charged clay/humus soil aggregates that act as a repository for plant nutrients.

Finally, another specialized group of bacteria, the ***denitrifying bacteria,*** convert nitrates (NO_3^-) back to nitrogen (N_2) where it can be used by nitrogen-fixing bacteria or return to the atmosphere. Figure 10 illustrates the Nitrogen cycle.

Figure .4-2 The Nitrogen Cycle.



Feeding the Soil versus Feeding the Plant

Any soil is only as good as its organic component. Soils low in organic matter are incapable of providing enough usable nutrients to plants and require chemical fertilizers. Until the early part of the 20th century, all fertilizers were "organic," in other words, derived from animal or plant sources. In the years preceding World War I, two German scientists discovered that ammonia could be chemically synthesized from hydrogen and atmospheric nitrogen in the presence of a catalyst under high pressure. Their discovery, called the **Haber-Bosch process**, revolutionized agriculture.

Chemical fertilizers are often referred to as ***"petroleum-based"*** because petroleum and natural gas are used as ***feedstock*** to produce ammonia. Both serve as sources of hydrogen. Crude oil is used to produce "***synthesis gas***," a mixture of carbon monoxide (CO) and hydrogen (H_2). Synthesis gas is then combined with atmospheric nitrogen in the Haber-Bosch Process to produce ammonia (NH_3). Natural gas, which contains methane (CH_4), is also used as a hydrogen source. The synthetic ammonia can be used directly as a fertilizer or be chemically converted to ammonium nitrate, ammonium sulfate, or urea. The potassium (K) and phosphorus (P) usually associated with nitrogen (N) in chemical fertilizers are mined.

Chemical fertilizers bypass most of the slow, steady organic nutrient cycles and simply dump soluble inorganic chemicals into the soil. They are sort of like "fast food" for plants. Nutritive values of chemical applications are generally not as high as what is released by *natural* decomposition. What the plant cannot immediately use is often washed away or lost to the atmosphere. Excess nitrogen in our streams and ground water reduces the quality of the water, and adversely affects fish, animals and humans. In addition, most chemical fertilizers cannot provide the complex blend of micronutrients plants need for optimal growth and they do nothing to improve the physical structure of the soil. Although chemical fertilizers provide a short-term "fix" that feeds the plant, ***only the slow process of decomposition and humus formation truly feeds the soil***. Table 10, at the end of this chapter, summarizes the important contributions humus makes to the soil.

In following chapters, we will learn how to optimize the natural process of organic decomposition in order to turn our organic wastes into a valuable end-product. As you will learn, finished compost and vermicompost are two of the best "meals" you can feed your soil

Your Pot of Gold: FINISHED COMPOST

Let's follow the decomposition process in an ideal yard waste compost pile.

- Equal volumes of browns and greens
- One cubic yard of materials
- Most particles are 1-2" in diameter
- Moisture is adjusted to 45-60%
- Oxygen is well distributed throughout the pile

Because the ambient temperature today is 70ºF, the psychrophiles are dormant and mesophilic microbes predominate. Our compost thermometer reads 70ºF. Within hours, the temperature begins to climb as the mesophiles are replaced by the thermophiles. By the third day, temperatures peak at about 160ºF and begin to cool down. We grab our pitchfork and turn the pile. The temperature drops to ambient immediately after turning, but, within hours, the temperature begins to climb again. We chart the temperature rise and turn the pile each time the temperature curve peaks and then drops. Each turn ensures that no particle escapes the thermophilic center of the pile. After about six weeks, we notice that the volume is reduced by half and our turning no longer results in a temperature rise. We gently lift a handful of compost and inhale. A sweet, earthy smell delights us. We can't recognize any of the original materials; everything looks like dark, rich, and crumbly. EUREKA! SUCCESS! Our wastes have been converted to ***compost***.

What is finished compost?

FINISHED COMPOST IS NOT EQUIVALENT TO CHEMICAL FERTILIZERS. Compost acts like humus to affect the physical, chemical and biological properties of the soil. Finished compost acts as a repository for the ***slow release of plant nutrients*** in a form plants can use and as a ***breeding ground for beneficial bacteria, fungi, protozoa, nematodes, insects and earthworms***. In general, finished compost contains ***less than 2% nitrogen, phosphorus or potassium*** (ref. Miller, *Soils in our Environment*, p236). It has a C:N ratio ranging from 10:1 to 20:1 (ref. Goldstein, ed., *Biocycle Guide to the Art & Science of Composting* p.179). It is neither acidic nor basic, with a nearly neutral pH of approximately 7.5.

Finished compost is a veritable gold mine of beneficial bacteria, fungi, protozoa and nematodes. Gardeners have known for centuries that compost helps plants fight diseases, and recent scientific research shows us how. Plants can be divided into two basic groups depending on their microbial requirements: ***bacterially dependent*** and ***fungally dependent***. Bacterially dependent plants (like row crops, annual flowers and grasses) need their roots covered by beneficial bacteria in order to utilize soil nitrogen and resist disease. Fungally dependent plants (like trees, berries and woody shrubs) require fungus-coated roots. In nature, plants derive these microbes from organically rich soil. When the soil is depleted, the plant roots become susceptible to pathogenic bacteria or fungi. Leaves, too, must be covered in beneficial microorganisms to protect the plant from air borne pathogens. Amending the soil with finished compost or spraying the foliage with a microbe rich solution repopulates the roots and leaves with beneficial microbes and helps the plant fight disease.

Using Finished Compost as a Soil Amendment in New Lawns and Beds

Poor soils are low in organic matter. The subsoil exposed during construction usually contains less than 1% organic material. To be effective, it is important to amend at least the top 6-8 inches of soil with sufficient compost so that the final soil contains between 8% and 13% organic material by soil weight. Professional landscapers test the soil before amendment and use fairly complex calculations to determine the correct amount of compost necessary to achieve 8-13% organic content. The homeowner can follow a simple rule of thumb: ***a 2 to 1 ratio of existing soil to compost, by loose volume will achieve the desired organics level***. Large quantities of compost may be necessary ***as one inch of compost spread over 1000 square feet is equivalent to***

approximately 3 cubic yards of compost (ref. Kolsti, Kyle F. et al.) Although a pick-axe works well in small areas, large areas will require mechanical tilling using a roto-tiller or even heavy tilling equipment. Usually, large projects require purchasing finished compost from a commercial source. It is important to ensure that the compost is free of viable weed seeds and diseased material.

Using Finished Compost in Established Beds and Lawns

To amend the soil in established flower or vegetable beds, gently work approximately ¼" compost into the soil around plants. Alternatively, simply top dress plants with compost; earthworms will carry it into the soil. For established lawns, the best time to amend the soil is during the spring or fall, after aeration. After aeration, spread a thin (approximately ¼") layer of finished compost over the lawn and water well. The compost will slowly work its way into the soil as water and earthworms carry it down and plant roots push it around.

Using Finished Compost as Mulch

A 2" to 4" layer of finished compost makes wonderful mulch. In addition to looking attractive, preventing evaporation and suppressing weeds, finished compost mulch is a slow-release source of plant nutrients and beneficial microbes. Finished compost is far superior to bark dust as garden mulch. Bark dust is basically raw wood chips and fine sawdust particles. If a bark dust is too fine, it may actually restrict airflow to plant roots. In addition, because bark dust is raw wood with a very high C:N ratio, decomposing organisms may "rob" vital nitrogen from the soil to balance the bark dust's high carbon content.

Using Finished Compost as Seed Germination/Potting Media

As you know, finished compost is not soil and cannot be used alone as seed germination or potting media. Finished compost is, however, a valuable soil amendment. To use compost as a potting media, it is important to sift it first to remove large (greater than ½" diameter) pieces. No more than ¼ to ⅓ of the total potting medium should be finished compost.

Finished Compost as a "Tea"

Compost tea is the water-extracted soluble fraction of finished compost. Gardeners and farmers have known the benefits of soaking seeds in or applying water extracts of compost to the soil and to plants for many years (ref: Rodale, *The Complete Book of Composting*). Modern research has validated their empiric insight by experimentally proving that **compost teas provide plant nutrients and reduce fungicide and fertilizer requirements.**

(The information in this section is derived from eXtension Webinar *Making and Using Compost Tea*, Catherine (CeCe) Crosby, Ph.D and Dr. Lynne Carpenter-Boggs, November 4th, 2015; Scheuerell, S.J. and W.F. Mahafee. 2002. Literature Review: Compost tea: Principles and Prospects for Plant Disease Control. *Compost Science & Utilization.* Autumn 2002; 10,4:313-338).

Compost teas can be divided into two general types: Nonaerated Compost Tea (NCT) and Aerated Compost Tea (ACT).

Nonaerated Compost Tea: NCT refers to compost teas made by methods that do not disturb, or only minimally disturb, the fermentation after the initial mixing. Typically, NCT is made by mixing finished compost in a 1:5 – 1:10 (v:v) ratio of compost to water and then allowing that mixture to ferment in an open container at room temperature without stirring.

Aerated Compost Tea: ACT is made by methods in which the water is actively aerated during the fermentation process.

Methods for Producing & Applying Compost Teas: Making compost tea of any type requires a fermentation vessel, compost, water, incubation and filtration. Sometimes, specific nutrients or isolated microbes are added to the mixture before, during or after fermentation. After fermentation, compost teas can be used undiluted or diluted. Teas are typically applied using a sprayer and most are filtered to remove large particles that would clog the nozzle before they are added to the sprayer. Sometimes chemical spray adjuvants are added to the tea to increase its ability to stick to plant surfaces. Finished compost should be used to make tea. It is shown that tea made from unfinished compost (that smells odorous or of ammonia) can be harmful to plants.

How does Compost Tea Work? Research into the modes of action of compost tea is in its infancy. Comparing scientific results is especially difficult because factors such as the type of compost feedstock, the age of the compost feedstock, the compost to water ratio, the fermentation time, the addition of and nature of nutrients during fermentation, the fermentation temperature and pH all affect the composition of the compost tea. Compost tea is low in nutrition; however it is brimming with beneficial microbes.

Research has not shown clear benefits of ACT verses NCT. It is observed that the microbial communities are different (Aeration does tend to increase the overall growth rate of such communities), but little is known as to what the best microbial community is.

The total microbial population of compost tea is correlated to increased disease suppression. This is a key point. A vibrant, diverse, living microbial community can be beneficial to disease suppression.

Compost tea can induce natural plant defenses: In other words, compost tea stimulates the plant to "fight a better battle."

Compost tea contains antibiotic-like molecules that suppress the growth of disease organisms. Research using heat sterilized or ultra-filtered NCT shows that an active heat stable, non-protein metabolite that acts like a plant antibiotic is either produced by the microorganisms during fermentation or was present in the compost used to make the tea.

Compost tea can act by competition. When applied to plant surfaces, the beneficial organisms in compost tea may successfully compete for nutrients or space, driving the disease organisms away.

Compost tea is not a pesticide. In research, it is an experimental pesticide. It is illegal for compost tea to be sold as a pesticide.

Compost Tea Recommendations to the Public: Several businesses are making and selling compost tea to the public. As Master Composter/Recyclers, we may be asked for recommendations. It is important to understand that the science of compost tea is in its infancy. Many factors may affect the quality or suitability of a specific batch of compost tea.
In addition, although unlikely, it is possible that human pathogens can be transferred from contaminated compost into the tea made from that compost. All commercial facilities have to go through pathogen and metal testing.