

Soil Biology and Composting for Gardens & Farms

Soil Commandments:

- Aerobic, Aerobic, Aerobic – Your soil and plants rely on aerobic microbes and processes so do your best to keep things smelling earthy!
- Watch Your Step – Avoid stepping on your garden beds as you only set back your soils biological processes and water holding capacity!
- No Naked Soils – Leaving your soil exposed will lead to erosion from wind and rain as well as bake the life and water out of your soil... mulch it or densely plant.
- Keep soil disturbance to a minimum unless you are absolutely aware of what the consequences will be and an effective way to remedy them.
- Keep soluble fertilizers on the store shelf and explore the power of cover crops, mulch, worm castings, compost, teas and extracts!

The Physique of Soil - Structure:

- Physical soil structure is made up of sand, silt, clay and organic matter, which have progressively more available nutrients in that order.
- Check out this link for some easy at home soil structure tests – <http://blogs.cornell.edu/horticulture/files/2012/04/HomeSoilTests-1nv3aiq.pdf>
- The more sand and silt your soil has, the more organic matter you will need to add as there is not enough available soil nutrients for your plants to access.

Chemistry in the Soil:

Chemical reactions in the soil have been the emphasis of soil science in the past but soil scientists are quickly realizing that soil biology is the major player under our feet. Nonetheless, here are some basic rules when it comes to chemistry in the soil.

- PH of below 7 is Acidic – Above 7 is Alkaline.

- Veggies, flowers, grasses and “weeds” typically like Alkaline Soils.
- Woody plants, bushes and trees prefer Acidic Soils.
- Veggies, flowers, grasses and “weeds” prefer their Nitrogen in “Nitrate” form.
- Woody bushes and trees prefer their Nitrogen in “Ammonium” form.

Soil Biology Unleashed:

Soil biology and the study of the Soil Foodweb are now proving that the chemical and physical processes taking place in the soil are largely due to the micro-organisms that inhabit the soil. Have a look [HERE](#) for some quick facts from one of my teachers Doug Weatherbee aka The Soil Doctor.

Some things to remember:

- Healthy soils are primarily dominated by either bacteria or fungi.

IMPORANT: Bacteria and fungi mine nutrients from the soil and exchange them to plant roots for plant exudates in the form of carbohydrates (simple carbs for bacteria, complex carbs for fungi). These exudates are excess carbs that a plant produces from photosynthesis and does not need for its own health. It instead prefers to receive a myriad of nutrients in exchange for these carbs so that it can grow into a nutrient dense plant instead of a carb rich (fat) plant. This is fundamental to the health of your plants, your soil, and your body and destroying this relationship will lead to more work for you!

Fungi

- Most perennials, woody bushes and trees prefer fungal dominated soils as fungi can out-compete bacteria in these environments and readily break down lignin and cellulose present in woody material.
- Fungi produce acids that assist them in the breakdown of lignin and organic matter causing the soil PH to move to the acidic side of the scale.

- Fungal hyphae in the form of Mycelium and Mycorrhizal fungi infect plant roots and create a symbiotic relationship where they transfer soil water and nutrients to the plant roots in exchange for carbon exudates. This essentially extends the reach of the plants roots in the soil without it needing to grow that large itself.
- Fungi are much more susceptible to disturbance in the soil including tilling, double digging etc. which is why perennial and forest ecosystems promote more fungal soils.

FUN FACT: The world's largest organism is actually a mycelium network estimated to be 2,384 acres in Oregon's Blue Mountains. Scientists estimate the age of this organism to be between 2,400 and 8,650 years old.

Bacteria

- Veggies, flowers, grasses and “weeds” prefer bacterially dominated soils as bacteria can out-compete fungi in these environments and readily break down simple sugars and green plant material.
- Bacteria excrete a slime which is alkaline and causes soil to move towards the basic side of the PH scale.
- Certain types of bacteria free floating in the soil as well as Rhizobium in root tissue are able to take nitrogen out of the atmosphere and put it into the soil. This is known as Nitrogen Fixation and is an example of a biological process leading to a chemical change – this was thought to be a strictly chemical process until recently.
- Bacteria are much quicker than fungi to inhabit disturbed soils and assist annuals and pioneer species (weeds) in getting established and building carbon back into the soil.

Healthy Soil:

These are some benefits of having healthy Soil Food Webs in your soil.

- Your plant roots will be so coated with beneficial microbes that pathogens will be kept in check and not allowed to compete for control over your plants.
- You will have a huge diversity of different types of microbes in your soil which leads to stability and security for your plants.
- Thriving microbial populations will allow you to create ideal PH and soil structure based on your garden needs and how you wish to manage your garden.
- Masses of fungal hyphae in the form of Mycelium and Mycorrhizal fungi will partner with your plant roots, essentially extending their reach and access to water and nutrients.
- Nutrient cycling will become a job the soil organisms take over and you will have less and less need to bring in any outside amendments or organic matter.
- Your soils water retention capacity will be increased lessening the need for watering, and creating more drought and flood tolerant plants.

Some Quick Ways to Unhealthy Soil:

Unnecessary Rototilling –

- Rototilling introduces an artificial amount of oxygen to your soil causing all the aerobic microbes to thrive and multiply which means they burn through the organic matter and unlock nutrients at a rate that plants cannot match.
- Plants are only able to absorb a fraction of nutrients unlocked in these situations and the rest are often leached out of the soil.
- Repeat this a few times and you can severely burn out your soils.
- Rototilling also destroys soil structure despite popular belief – all the water and nutrient channels, nooks and crannies created by beetles, earthworms, and other microscopic organisms are destroyed when you rototill and although you may get fluffy soil out of it, this can be easily compacted and eroded. Let humus and organic matter fluff soils!
- Whenever soil disturbance occurs, especially in the case of rototilling, dormant seed beds beneath the soil surface are brought up and often have

the light, air and temperature requirements needed for germination. By top dressing with mulches and compost you keep these seed beds down and unable to germinate and compete with your garden.

- Rototilling decimates fungal populations in soils and therefore sets back succession. If you are destined to grow brassicas in fungally dominant soils, this may be your best bet to do so. However, you may want to use your best soils to grow berries and fruit and dig up some new lawn for your brassicas where they are much more likely to thrive.
- Hardpan is a term that describes the compaction that occurs right beneath the length of your tillers tines. This is much more of a concern in high-clay soils and creates a catchment surface under your garden soils that water cannot penetrate. Water then pools on this surface and goes anaerobic which leads to breeding of certain bacteria that create alcohols that are toxic to plants. Plant roots are then restricted to only the soil above this “hardpan”. This causes susceptibility to drought and lack of nutrients where normally a plant could dive deep into the soil for these key lifelines.

FUN FACT: Rototilling does have appropriate uses, especially for those wanting to tear up their lawn to plant food etc. The key is to reduce the need for tilling and definitely not tilling multiple times a year. When you do till make sure your soils are not wet as this can lead to hardpan, and do your best to follow a tilling with a spray of biologically active and AEROBIC compost tea or extract to restore life to your soil. Also make sure you cover up that naked soil with a mulch to prevent erosion, baking, and leaching of you soil.

Keep reading for more info on compost teas and extracts.

Fertilizers:

Most of this information goes for all soluble nutrient fertilizers, organic or not. N-P-K is usually the “value” given to a particular fertilizer mix and stands for the Nitrogen-Phosphorous-Potassium ratios included. Often these nutrients are the

only ones included and trace nutrients are completely lacking which leads to nutrient lacking food, instead of nutrient dense food.

The 1-2-3's of fertilizers:

1. When plants are fertilized they are given free nutrients (most are solely NPK) and your plant is sent a signal that it no longer needs to trade away its excess carbs to soil microbes in exchange for nutrients.
2. When this exchange stops, soil microbes are left empty handed and either die (through starvation or poisoning depending on the fertilizer ingredients), or they are forced to leave.
3. Your plants then store those excess carbs and get nice and fat but they lack most of the nutrients needed for healthy food.
4. If you stop this practice of fertilizing there are no soil microbes to pick up the slack and no resilience built into the plant anymore so you are forced to continue fertilizing.
5. Since soil microbes are your best defense against plant diseases and pathogens and you have kindly asked them to vacate, fertilizing leaves the gate open and your plants susceptible to attack.
6. Fertilizers are also only effective in the Rhizosphere (directly around plant roots) so spraying a fertilizer on your soil means most of it will be leached away by watering and rain.
7. To compound this, most fertilizers are high in Sodium which will lead to a salting of your soils!

The Solution: If you have had your soils tested and are in need of certain amendments, add them to your compost pile so they can be locked up and slowly released by soil biology to your plants. Rely on cover crops, mulches, compost, and compost teas and extracts to give your plants the nutrients they need!

Manures:

- Raw manures can contain pathogens which can either be killed by heat or time. Properly made hot compost piles are a great way to kill pathogens quickly, where static compost piles are better if you have the time. The key is PROPERLY MADE!!!
- Manures are not a stable source of nitrogen unless they are tied up with carbon like in a properly made compost pile. That bedding you threw in with your animals is usually an insufficient amount of carbon for the amount of nitrogen in manures.
- Piling raw manure or even manure with bedding will lead to a leaching or gassing away of nitrogen as well as creating anaerobic conditions in your pile. This will lead to the breeding of anaerobic bacteria that once again create alcohols and are extremely detrimental to your plants and garden.
- Aged manure, although maybe pathogen free have leached and gassed away the large majority of their available nutrients and lack the beneficial biology that proper compost does. Sure it will give your garden a bit of a boost but you can receive even better results with 4 -5 wheels barrows in a proper compost pile than you can with a dump truck of aged manure. It's all about biology and nutrient density!

Manure Teas A BIG NO-NO: Leaving a bag of manure in a barrel of water is asking for pathogen problems and under anaerobic conditions (which it will be unless an air pump is installed to actively aerate it) will virtually assure the presence of Ecoli which thrives in anaerobic conditions. Yes you will get some nutrients out of it but there are much safer and more effective ways to get better results. Once you have made that amazing aerobic compost you are about to learn about, take a bag of it and be sure to follow best practices for brewing up a super biological tea or extract to put on your garden.

The Silver Bullets of Healthy Soil

Thermophilic (hot) Compost:

There is a ton of misinformation around composting that has been passed around for a long time. Luckily there are some very dedicated people working hard to bring the proper information to the world and showing the scientific analysis to back up the idea that “Not all composts are created equal”. There are some ideals that you want to work towards when building your compost piles and it takes some practice to get these working to your advantage. The good news is that as long as you follow some guidelines and are observant of what you put in to your pile and what is happening to your pile, you can adjust most mistakes with proper management.

Ideal Outcomes:

- Yes compost contains nutrients for your garden, but most importantly proper compost is an inoculant of biology for your soil that will partner with plants and improve their capacity to access water and nutrients as well as fend off pathogens and diseases.
- Your goal as a composter is to create ideal conditions in your pile for the most diversity and greatest number of beneficial microbes to procreate and thrive!

Materials:

Compost piles should consist of the following:

- Carbonaceous materials – Brown leaves, straw, woodchips/shaving, newspaper etc.
- Nitrogenous materials – manures, grass clipping, coffee grounds, urine, kitchen veggie scraps, leguminous hay. MAKE SURE YOUR MANURES ARE

FROM A SAFE SOURCE AND WITHOUT ANTIBIOTICS, HORMONES, OR “CIDES”!

- Green materials – non-leguminous hay, fruit scraps, garden waste - stalks, roots, weeds etc.
- Water – Piles should have 50% moisture or a wrung out sponge feel... give a handful a squeeze and no more than a couple drops of water should come out.
- Oxygen – Your biggest task is to keep your hot piles Aerobic, Aerobic, Aerobic!!! This means avoiding matting or clumping materials by chopping and mixing everything as much as possible. This also means monitoring and flipping your pile when it is needed and not the next day!
- Amendments – if and only if you have got a soil sample and a nutrient deficiency is identified, now is the time to add your soft rock phosphates or other amendments.
- Cover – To avoid your pile getting too wet/dry or leaching away nutrients, covering your pile can be very important. The ideal is a product called CompostTex that you can check out [here](#). Tarps can be used but they do not allow air in so try to prop them up over the pile instead of promoting suffocation.

Fungal vs. Bacterial:

Just as we are seeking to match our garden soils with the vegetation we plan to place there, we want to build our compost piles to match that vegetation as well.

This means if you are planting many fruit trees and shrubs or are trying to move your soil forward in succession towards more perennial systems you will want to make fungal dominated compost. If you need to give your veggies or annuals a boost, get the bacteria going!

Speeding Up or Slowing Down:

- It is much easier to heat up a pile that is too cool than it is to cool down a pile that is too hot!

- Imagine you are driving a semi truck down a hill and your nitrogen is your gas pedal while your carbon is your brake...
- Best to put too much carbon in to begin with and be able to add a small amount of manure, urine or coffee grounds (gas) than to try to slow things down and have to add massive amounts of carbonaceous materials (brake).

Approximate Ratios for Composts:

- If you are looking to create a fungal dominated compost pile, try to use 15% High Nitrogen Material– 35% Green Material – 50% High Carbon Material.
- For a bacteria dominated compost pile, use 20% High Nitrogen Materials – 45% Green Materials – 35% High Carbon Material.
- These are ideals but can be mixed and matched to create the same result, remembering to avoid too much High Nitrogen Materials!

Size Matters: You will struggle to get sufficient temperatures in your compost pile unless it is a minimum of 1 cubic meter or 3 feet x 3 feet x 3 feet. A 1 cubic meter pile will end up being 3-4 feet tall and 6-8 feet wide in a mountain shaped pile. Be sure to keep it under 3 cubic meters as well or combustion can occur in the pile... and it's too much work to manage with a pitchfork.

Building Your Pile:

Hopefully by now you have gathered a sufficient amount of organic matter to build your pile, whether it be bags of leaves, manure from a safe source, or woodchips from a local sawmill. In the future you should aim to source all of the materials needed from your site alone, closing the nutrient cycle on a home or farm scale. Before you start building your pile, be sure that you have enough room for at least two compost piles so you can flip your pile back and forth.

Now for the process:

- Start by deciding if you will make a bacteria or fungal dominated pile and use the ratio's above to get your head around how much of each material you will be using. For demonstrations sake we will go through building a fungal dominated pile at a ratio of 15%-35%-50%.

- I like to use a wheel barrow for my measuring cup and since we are using ratio's you don't need to keep track of specific volumes. We could say fairly accurately that our High N – Green – High C ratios of 15-35-50 translate roughly to 1-2-3. This means for every wheel barrow of High N material I add, I will add 2 wheel barrows of Green and 3 of High C. I will also add an extra Green and extra High C at the end of the pile to make up for the slight mathematical inaccuracy.
- I like to lay down a layer of High Carbon material to begin with, in a 6 foot diameter circle as this provides a nice bed for my other materials to be caught and held, instead of rolling away or making a mess of my working space.
- I then follow my 1-2-3 recipe, layering materials and spreading them out as much as possible until I have reached a sufficient 1 cubic meter or larger. This is most often dictated by whatever ingredient I am shortest of... so once the High C material is gone I stop adding the High N and Green even if I have piles of it left.
- Now you have your big pile of materials in front of you somewhat layered and probably looking a little dry... that's ok, because now comes the real pile build.
- Remember that open space you allocated for flipping your pile onto? You are going to move your existing pile there now. Just like baking, we got all the ingredients into a bowl but to effectively mix them we need to blend them.
- Pitchfork by pitchfork, flip and sift your pile into its new location so that it is as homogeneous and consistent as possible. Don't let there be pockets of manure without carbon or they will cause problems.
- As you flip and sift this pile, have your hose ready and spray down the materials in the new pile as you build. You will be surprised how much water it will take to do this initial soak, especially if the majority of your materials are quite dry to begin with.
- The reason for adding water at this stage instead of during the initial piling is to save your back from forking that extra few hundred pounds of water.

- Alright, so you have flipped, sifted, mixed and moistened till your heart's content and you have a homogeneous mountain of organic matter... now it's time to get that cover on it and let it do its thing!

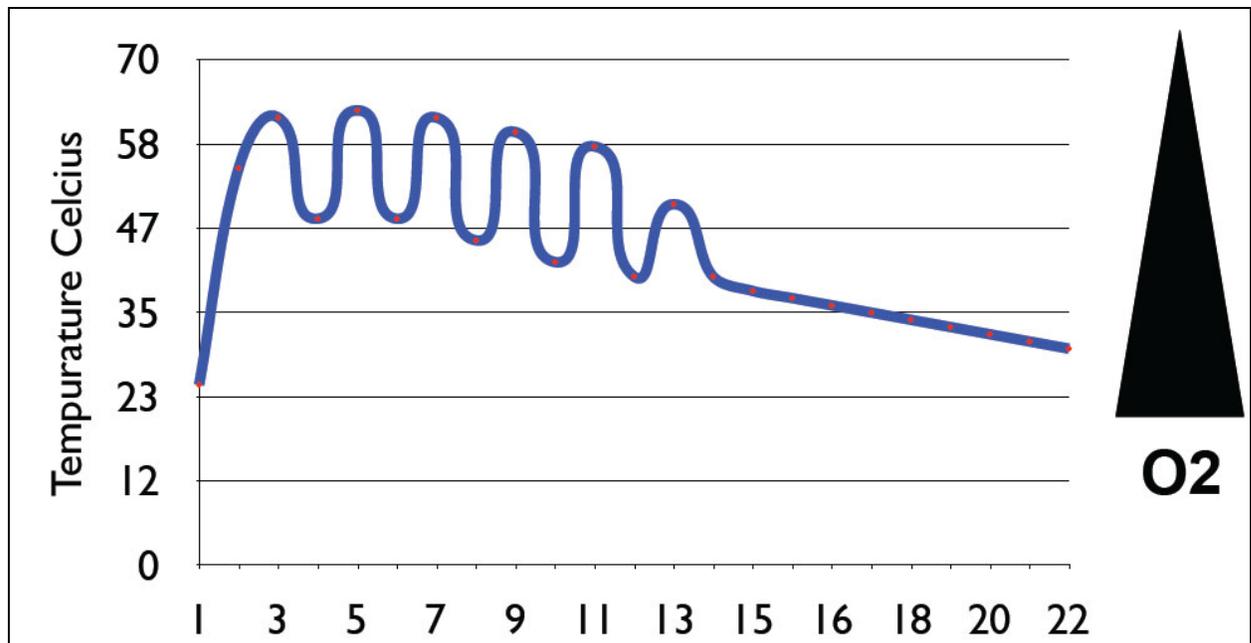
Managing Your Pile:

There are a few main things you will want to watch for in your thermophilic compost pile:

Temperature:

- I suggest buying a compost thermometer that is at least 2 feet long so that it can reach the middle of your pile and you can monitor it accurately. This purchase is essential and will cost as little as \$13.00.
- When monitoring your compost temperature you are looking for The Hottest spot in the pile to be your marker for turning so poke around until you find it. Usually in the center of the pile about 2/3 of the way to the top of the pile because of rising heat.
- Your goal is to get your compost pile above the 55 degree Celsius mark but to keep it below the 63 degree mark. Getting above 55 will allow the heat to kill weed seeds, and destroy pathogens, pests, and parasites. Letting your pile go above 63 degrees will kill off beneficial biology as well as quickly move the pile into an anaerobic stage which will produce strong acids and alcohols as well as cause many other problems.
- If your pile exceeds 60C and continues to climb it is best to do a pile turn (outlined below) and to add some more High C material.
- If your pile is struggling to reach 55C then pee on it a few times or flip it and add a LITTLE High N material (a third to a half of a wheel barrow) until it reaches sufficient temperature.

Here is a diagram of an ideal compost temperature and the turning times – note that you may need to adjust this depending on how fast or slow your pile heats up. You will get better with practice.



Aerobic Conditions:

- Usually you can determine this by smelling your pile. If it smells bad, it probably is bad. The only time your pile may smell off-putting is in the very beginning stages because of the raw manure you may have added, otherwise it should have an earthy smell to it. Rotten smelling is not what you are looking for and this perpetuates the myth that all composting stinks.

Actinobacteria: The most common sign of an anaerobic hot compost pile is the overwhelming presence of Actinobacteria. This is a white ashy like substance not to be confused with Mycelium (highly beneficial) which has visible white strands. There is always going to be some Actinobacteria in a hot compost pile but you do not want it to take over your pile. Try to keep it in check (below 15% of total pile) by turning every couple of days until your pile starts to cool off for good and you should prevent this. If your pile gets neglected for some reason (it happens to all of us) and it is filled with this white ashy substance when you go to turn it – DO NOT add this compost to your garden. You can either work it into future compost piles bit by bit, or let it cure as static compost pile until next year.

Moisture:

- Remember the wrung out sponge feel! Turning your pile is the perfect time to layer in some water as letting it dry out will slow microbial activity.
- If you have your pile properly covered you will not run into your pile becoming too wet unless you are the one that adds too much water.

Turning Your Pile:

- Now that you have let your pile reach optimum temperatures and have decided it is time to turn it, you need to think about what part of the pile has been “cooked”. The middle has reached those optimum temperatures but the outsides and bottom have not, so it’s time to turn the pile inside out.
- Scrape the outside 6-10 inches down off of the pile – pile this as high as possible as this will become the center of your new pile once you’re done turning.
- Then scrape around the bottom of the first pile and leave it separate from the remainder of the pile. What you will have left is the hottest part of the pile.
- Take the middle of the pile which should be steaming and start making the base for the outside layer of the new pile and build up.
- Take the remainder that you set aside and cap the pile.
- It is important to be mindful of each forkful of compost and sift it to reduce matting. This also allows you to place the hottest or possibly anaerobic parts of the pile in the appropriate cool place and vice-versa.

Curing process:

- Once your pile has been flipped a number of times (usually between 4 and 6 times over 2-2.5 weeks) it will go into the curing process.
- Decomposition is still occurring at this stage and as your pile cools the environment in your pile will become more conducive to fungal populations thriving.

- Flipping the pile in the curing stage is unnecessary and will actually destroy fungi that are living in your pile. Best to leave it be and let those fungal numbers explode!
- Fungi are going to break down the more complex carbohydrates and lignin that are remaining in your pile (primarily the woody material) and really start to out-compete the bacteria.
- The longer you let this take place the more fungal dominated your pile will be. If you are looking for a bacterial dominated pile, its best to use it in the first few months.
- A properly turned compost pile can be ready to go in the garden as early as approximately 2.5 weeks when the pathogens and weed seeds have been taken care of and the biology in the pile is thriving.
- Compost does not need to look like coffee grounds for it to go on the garden, so don't be discouraged if your pile isn't looking like "black gold" when you're done with it. There is nothing wrong with adding organic matter coated with biology into the garden where it will become food for your plants.

Application:

There are two main ways to get compost and it's amazing benefits into your soil and that is in a solid or a liquid form.

Top Dressing:

- To apply your compost to your garden soils you can simply top dress your beds with anywhere from a ¼ inch to a few inches of compost. You can work this into the top few inches of your soil if you wish or leave it on top. Either way be sure to cover it with a mulch so the soil life is protected from the elements.
- It is also best when applying compost to your soil that you wait until the ground is thawed and the soil life has started to come out of dormancy. Taking microbes from the comfort of a warm compost pile and putting them on frozen soil is not ideal.

- I always take a handful of good compost and throw it in a transplant whole before putting my seedling in to ensure a healthy start.

Actively Aerated Compost Teas and Extracts:

- Can be applied with a watering can, hose attachment or large tractor mounted sprayer.
- These are very effective tools for delivering a biological and nutrient dense inoculant to your soils.
- Great for applying after a necessary soil disturbance like tilling to bring life back to the soil.
- A huge advantage of teas and extracts is that they can be spread over larger areas without a huge amount of compost.
- A disadvantage is that you do not get the benefits of added organic matter in your soil.

A Good Brew: These are not your grandparents manure teas we are talking about. There has been a ton of research into the immense benefits of properly made aerobic compost teas and extracts. [HERE](#) is a fantastic resource from one of my teachers Rob Avis of Verge Permaculture that gives all the ins and outs of how to make the right brew without breaking the bank.

Worms and their benefits.

Resources:

<http://vergepermaculture.ca/blog/2010/06/02/story-soil/>

http://www.amazon.ca/Teaming-Microbes-Organic-Gardeners-Guide/dp/1604691131/ref=dp_ob_title_bk

<http://soildoctor.org/>

<http://www.klickitatcounty.org/solidwaste/fileshtml/organics/compostcalc.htm>