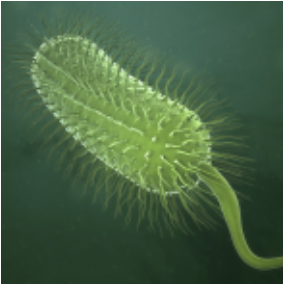


The Holistic Gardening Handbook

by Phil Nauta

Creating health and abundance in your organic garden

Condensed Version

The art and science of the new organic gardening

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Note: This is a highly condensed version of the original text - more info at www.smilinggardener.com/book

About The Author

Phil grew up working for his parents in their garden center. He maintained the nursery stock in the yard and did some of the landscaping. He was also in charge of maintaining their 9 hole, par 3 golf course. He continued to do this through University while he obtained his business degree and commercial pilot's license. Not content with flying, he went on to complete a Certificate in Organic Landscape Management from Gaia College.

Since then, he has played many roles in the organic gardening world. He started a gardening business called Only Organic, later taken over by his sister. He received his Permaculture Design Certificate and completed a Certificate in Sustainable Building and Design from Yestermorrow Design Build School. He became a Certified Organic Land Care Professional through SOUL, The Society For Organic Urban Land Care. He later served as SOUL Treasurer for 3 years and continues to maintain their website. He started The Organic Gardener's Pantry to sell high quality organic fertilizers. He has taught courses for Gaia College and helped put together their cutting edge online learning environment.

He works with his wife Heather, a Registered Holistic Nutritionist, to help people improve their health and the health of their gardens and the planet. When he's not in the garden, he's in front of the computer trying to get the word out, or at the piano, pretending he's Duke Ellington.

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I wrote “The Holistic Gardening Handbook” in 2010/2011. It was eventually published in 2012 by Acres U.S.A. as “Building Soils Naturally.” At some point long before that, I had created this very condensed version of the original book, thinking it might be a useful thing to have around. I hope you find it so.

After writing the book, I went on to create The Smiling Gardener Academy, my comprehensive online organic gardening course. Most of my time these days goes into joyfully working on that course and interacting with the people in it. If you would like access to hundreds of step-by-step videos on how to create a healthy organic garden, you can check it out at www.smilinggardener.com/academy

Hope you enjoy!
Phil

Introduction

The lessons in this book apply to both ornamental and food gardens. Many of us are becoming more and more interested in growing food, so my examples often center around that. We know that most produce from the grocery store doesn’t have the nutrition it used to, and we’re excited to grow our own nutrient-dense fruits, vegetables, grains, nuts and seeds - even mushrooms, which are fungi.

In the last half of the 20th century, pesticide use increased by 1000%, yet the percentage of crop loss due to insects nearly doubled. During this same period, the majority of our topsoil has been lost. The majority of our groundwater, lakes and streams are also polluted, along with our air.

Fortunately, the earth will eventually repair itself, and we can take action right now in our own backyards. We can vastly

improve our own soil and grow high-quality food. We need to, because although agriculture has drastically increased the amount of food it can grow during the last 60 years, that food has less nutrition. Some research shows that the nutrients in our food are down 60 to 70% on average.

We've come to think of large crop loss to plant predators as being natural, but this is simply not natural at the scale in which we're seeing it today. Despite the admittedly grim state of current growing practices, this book is an uplifting look at how we can grow food that looks like it's supposed to look and tastes like it's supposed to taste, that's so nutrient-dense it slowly dehydrates on the counter over several months instead of rotting in a week. We can grow food that has many, many times more nutrients than the food in the grocery store, even the food from the organic section. For this, we need healthy soil, and it doesn't happen by accident. It happens through a holistic approach that integrates many disciplines.

It's called *The Holistic Gardening Handbook* because I like to look at gardening as managing a whole ecosystem instead of just separating it into parts. We are in the age of scientific reductionism, breaking things into smaller and smaller parts. This has its uses, but we often forget to step back and look at the whole system, at how the constituent parts interact. In this book, you'll learn how to address the whole system.

Part 1 covers the soil food web - bacteria, archaea, fungi, protists, animals and plants - including the good guys and the "bad" guys - the plant predators and weeds. Part 2 teaches you how to analyze your soil both qualitatively and quantitatively in order to make garden management decisions. Part 3 gets into the biggest section, the 7 strategies for creating health and abundance in your organic garden. Part 4 brings it all together into a garden health management action plan.

Chapter 1
The Soil Dwellers

The “soil food web” refers to the inhabitants of the soil village. They make the soil and maintain it. They transform the minerals and organic matter in the soil into something that can support an abundance of life. Some of them pull nitrogen out of the air and change it into a form that they, and plants, can use. Some bring nutrients directly to plants in exchange for food from those same plants.

They also work to protect plants from plant-feeding predators, both in the soil and above ground. If we use toxic chemical fertilizers or pesticides, or withhold water from the landscape, or do a lot of deep rototilling or other soil disturbance, many of these soil workers probably won’t be around for very long.

What They Need

Some microbes breathe air, just like us. They’re called aerobic microbes. Other microbes die in the presence of gaseous oxygen, so they live in places where there is none, such as deeper in the soil. They’re called anaerobic microbes, or anaerobes. Others switch between oxygen and other methods. Microbes need water, some more than others. Some microbes need light. In fact, some of them photosynthesize like plants. They all function best in their own specific temperature range.

Microorganisms

Bacteria are the tiniest members of the soil food web. They are single-celled organisms - they each have just one cell. There are hundreds of millions of them in a gram of healthy compost,

even a billion. Bacteria occupy the majority of the leaf and root surfaces of a plant. They break down simple substances and toxins and aggregate the basic building blocks of the soil.

Fungi may be single-celled (such as the yeast that makes your bread, yogurt, wine and beer), or they may have billions of cells (like in a mushroom). A mushroom is the fruit of certain types of fungi, but the majority of those fungi's biomass is actually underground, winding through the soil kind of like a microscopic root. They eat complex organic materials that most other living things can't easily digest (such as lignin), and they harvest minerals from rocks that are virtually inaccessible to other organisms until released by the fungi (such as phosphorus). Like bacteria, fungi get food in the form of carbohydrates from the plants in exchange for their services.

Protists are the outcasts in the microbe world, whose main distinguishing feature seems to be what they aren't - they're neither bacteria nor fungi nor animals nor plants. A protozoan can eat 10,000 bacteria in a day. During this process, nitrogen is converted to ammonium, upon which many of your plants will happily dine. We say that bacteria and fungi *immobilize* nutrients by storing them in their bodies, and then protists (along with other microbes, plants and animals) *mineralize* these nutrients - meaning they make them available again.

Animals

Animal manure is organic matter and fertilizer for the soil, and it often contains seeds transported from somewhere else that will germinate and grow into plants. Plants are pollinated by animals, especially birds, bees and butterflies. Insects (such as mites) and microscopic animals (such as nematodes) are largely responsible for making minerals available to plants as a result of eating microbes, just like the protists.

Plants

Plants photosynthesize: they take carbon, water and nutrients from the soil and air, lounge out in the sun all day, say some kind of magic spell or something and tada - they get a bit bigger.

Plants make it rain - it turns out that when you cut or burn down a rainforest, it often stops raining in that area. They also make oxygen. They help make soil and then they help protect it. They are an integral part of the soil food web. Their roots work through the soil, create fresh organic matter as they constantly grow and die back, and actually dissolve rock to form soil. Their bodies turn into organic matter every autumn when the leaves fall, and also at the end of their lives.

Cooperation and Competition

In the soil food web, there is competition, but there is also cooperation. The cooperation between plants and microorganisms is fascinating. The microbes bring food and water to plants in exchange for other food that is made by the plants. Plants can send well over 50% of the carbohydrates and thousands of other substances they make during photosynthesis into the soil as exudates (food) for microbes. The microbes give plants the food they need in return, as well as protection from predators.

In nature, this cooperation and competition produces environmental prosperity, and it can do the same In our gardens. The reason it's helpful to learn about the members of the soil food web is because our main goal is to support them in order to have a healthy garden. Knowing what they need helps us achieve that goal.

Chapter 2
Plants

Plants love music. The right sounds can produce tremendous improvements in growth, while the wrong sounds can do just the opposite. They prefer jazz and classical to rock and heavy metal. By far the most noticeable positive reactions have been to classical Indian music. Rice harvests have been grown that were from 25-60% higher than average, and nearly 50% higher for peanuts and tobacco.

How Plants Eat And Breathe

Plants "eat" primarily by photosynthesis. They need carbon dioxide, water, proteins, minerals and Mr. Golden Sun. Interestingly, they are composed of about 95% carbon, oxygen and hydrogen, so the proteins and minerals are only a small part, but vital. Even though the minerals make up only 5% of the plant, they are crucial. We also have a role in making sure our soil has the right mineral balance because we are planting many things that probably wouldn't be growing there if they had the choice.

Like us, plants breathe oxygen. While only the green parts photosynthesize, all cells breathe. The main purpose of breathing is turning those carbon-based molecules from photosynthesis into more useful forms of energy. The roots need to breathe, too, so they need air in the soil. The soil food web helps make big pore spaces for this air.

How Plants Survive

Plants are exceptionally good at surviving. Some have thorns

to ward off animals. Some have thick bark, or thick hair, or wax on their leaves. They build themselves with ingredients that are difficult for microbes to digest. When their branches get injured, they just discard them and grow a new one.

Plants produce chemicals for defense. Some of these chemicals become our pharmaceuticals and pesticides. They also employ others to help defend them - bacteria, fungi, and even insects. Some plants, especially annuals, survive by simply growing really fast to get above plant-feeding animals and by producing tens of thousands of seeds per flower. Longer-lived plants spend more time building strong root systems, difficult-to-digest plant parts and bark, and toxins.

In order to produce strong bark, build strong leaf scars, produce toxins, cooperate with other species, and produce many seeds, plants need healthy soil. Plants are exceptionally good at surviving, if they have the raw materials they need.

Air

While some plants are pollinated by birds, insects and other animals, all conifers and grasses and many deciduous trees rely on wind for pollination. That's how they mate.
Our friends in the soil need air, too. Most of the helpful bacteria and fungi are aerobic. They need air just like us. So do plant roots.

A healthy soil is made up of approximately 25% air. This is not achieved long term by rototilling or aerating the soil. In fact, that can destroy the soil structure if you do it too often without incorporating organic matter. Proper air in the soil is achieved not by us, but by the hard work of the microorganisms, insects and earthworms building themselves cities. Our only job is giving them the tools they need to do this.

Temperature

Plants grow in a certain temperature range, which varies depending on where the plant evolved. When it gets too hot, they protect themselves. We can help when we spray a little bit of water on the leaves during a very hot afternoon. Before it gets too cold in the fall, annual plants have produced seed and died, perennials and other deciduous plants have stored their nutrients back in their stems and roots before discarding their leaves, and other chemical changes have occurred.

In the soil, most microbes don't get to work until it's warm enough for them. Nutrients in the soil become available to plants in the spring just when they need them, although there may be a temporary deficiency in certain nutrients until certain microbes get moving. A compacted, wet soil stays cooler much longer. In our garden, we may temporarily rake the mulch layer aside so the air and sun can quickly warm the soil.

Nutrient Access Versus Nutrient Quantity

It's important for plants and microbes to have consistent access to a small amount of many different nutrients. In fact, that is much more important than sporadic access to a large amount of nutrients - as is the case when we pile on all of our chemical fertilizers, or even mineral fertilizers, at one time.

This is what organic matter does for us in soil. It holds onto nutrients and is composed of nutrients. Through the process of breakdown, these nutrients slowly and consistently become available to plants. Ana Primavesi, Elaine Ingham and thousands of people around the world have confirmed that plant health is improved when the soil food web is improved, one of the main reasons being because microbes make nutrients more available to plants.

Chapter 3
Plant Predators And Weeds

We and other animals prefer plants that are healthy and full of nutrients. But why do insects and diseases eat our plants? We tend to think insects and diseases are making our plants unhealthy, but actually, they are there *because* our plants are unhealthy.

This is one of the biggest shifts we need to make in our thinking when moving to organic gardening practices, and to me it's absolutely fascinating. While animals prefer healthy plants, insects and diseases prefer the opposite. They choose plants that have a nutritional imbalance of one or more nutrients. They literally do not possess the enzymes necessary to digest healthy plants. A lawn with a balanced soil will not be overtaken by weeds. They could never compete with the grass. Our goal is health management, not pest management.

The step up from managing plant predators is what we looked at in the last chapter - how plants have multiple methods of protecting themselves if they have the tools they need to put those methods in place. The final step is optimal health in the plant to a point where predators can't digest the plant and hardly bother trying, so that the plants don't even have to devote much energy defending themselves.

Insects

Insects sense their surroundings with their antennae. That's how they find a mate and how they find their food. These antennae interpret electromagnetic frequencies in the infrared spectrum, which is right beside the visual light spectrum we can see.

Plants also emit pheromones that insects interpret as “food”. Not all plants emit these pheromones, though. It turns out that only *sick* plants emit them in such a manner as to be seen as food! The presence of insects tells us our plants are sick. It’s not the predators’ fault.

The same goes for disease. Disease refers to bacteria, viruses, fungi and other microbes that eat plants or animals. Like insects, each plant-feeding microbe generally has only a few species of plants it eats, and they eat sick plants.

Weeds

Weeds come with definitions such as “a plant growing where it is not desired. I like to define weeds as “beautiful, resilient plants that are doing everything in their power to improve our imbalanced soil conditions.” And yet for some reason we have it in our mind that we need to get rid of them. In fact, perhaps half of “weeds” have actually been used as medicinal plants and many of them are exceptionally tasty.

Weeds heal the soil. Each weed can grow in different imbalanced soil conditions and work to bring the soil into balance. It is a common myth that weeds and more desirable plants like the same soil conditions. In reality, most of the really pesky weeds get sick in balanced soil conditions. Like insects, they thrive on imbalance. Here are some ways weeds help out:

- Bring minerals and water up from deep in the soil.
- Break up hardpans and compaction and control erosion.
- Increase the organic matter content of the soil.
- Tell us a tremendous amount about the nutritional condition of our soil through their presence and growth habit.
- Fix nutritional imbalances, vastly improving soils.
- Provide homes and food for microbes and animals.

Weeds are there because they are the most suitable plant for the job, more suitable than what we're trying to grow. They persist despite our efforts to get rid of them. They're able to outcompete other vegetation when that vegetation is sick, growing in the wrong spot or poor soil conditions. When fertility, soil texture and soil structure are altered, the weed population will also change; and importantly, when these factors are improved, the desirable plants will outcompete the weeds.

If you do a really good job of balancing the soil, plant-feeding insects will leave your plants and move over to the weeds, as the weeds actually become sick in healthy soil. The root cause is the nutritional imbalances and an unhealthy soil food web. Then there are even more details we've learned about specific weeds. There are weeds for every situation: too wet or dry, poor drainage, not enough air, compaction, improper decay of organic matter, improper nutrient exchange, and so on.

Health Management

This chapter presents a very exciting and important concept - health management. Rather than treating disease, we remove it from the picture by creating health. It must be noted that the garden is a dynamic environment, so even healthy plants are probably always fluctuating in and out of a state of optimal health based on any number of factors.

Even in a fairly healthy soil, we could get a month of dry days in the summer, an early freeze, a loss of soil energy in the fall, or any number of conditions that impact the health of a plant to the point where some predators can come and dine for awhile. But if we can accomplish the goals laid out in the rest of the book, healthy and predator-free plants will be the main outcome.

Chapter 4
All About Soil

Soil gets started when rock is broken down by mechanical, chemical and biological means. This process can take thousands of years. Nitrogen is needed for plants to grow, so nitrogen-fixing plants arrive on the scene first. They don't actually fix nitrogen, but they partner with bacteria that do. The plants can then grow bigger and this is the start of organic matter. Sand and silt are both mostly quartz rock made small, whereas clay is formed from a chemical reaction between certain minerals. The significance of this difference is next.

Soil Texture

There are 3 sizes of soil particles. From biggest to smallest, they are sand, silt and clay. Sand is gritty and it doesn't stick together. Silt is smaller and more powdery, but is still separate grains. Clay particles are much, much smaller and they join together to form a sticky substance kind of like play dough.

So *soil texture*, a bit of a misleading term, is actually a specific way of describing the relative particle sizes in your soil. It refers to the percentages of sand, silt and clay that are present. You probably have all three soil particles to some degree.

The quickest way to learn what kind of soil texture you might have is to take 1/3 cup of loose soil, remove any debris, and slightly moisten it uniformly throughout the sample. Then roll it into a ball. If you have a hard time doing this or if it breaks easily under pressure, the predominant soil is sand. It will also feel a bit gritty. The more it stays together, the more silt or clay you have. Try to roll it out into a cylinder. The longer the cylinder you get, the less sand you have. It can be tricky to dif-

ferentiate between silt and clay, but silt is smoother with more individual grains and clay is stickier with no discernible grains. Clay can also stain the hands. There is another test that I prefer called a sedimentation test, described in the full book.

Soil Structure

Soil structure looks at how these individual soil granules clump together into various shapes and sizes and what that means for factors such as water and air movement, compaction, biological activity and root growth. This soil aggregation is performed mostly by microbes, plants and small animals.

If your soil is dominated by sand, the resulting structure will likely allow for excellent water infiltration and drainage, but not that much of it will stay around. This is because the relatively large size of the sand grains creates many big pore spaces for air, but not as many small spaces for water. While the water holding capacity of a sandy soil isn't great, there is a lot of air and not a lot of compaction in a sandier soil.

If your soil is dominated by clay, the resulting structure will likely result in less than ideal infiltration and drainage. Water won't go down as deep because there are so many small pore spaces near the top of the soil to hold it, and it will not drain as well. Of course, that means it holds onto more water and needs to be irrigated less often. Also, with fewer big pore spaces, there's less air in the soil and less resistance to compaction. Silt falls in the middle.

What about organic matter? It turns out that it does everything right in terms of soil structure. It infiltrates brilliantly and drains freely, but not before holding onto a tremendous amount of water. It still allows for plenty of air in the soil, but it resists compaction.

Fertility

The inherent fertility of your soil is dictated by the rock from which it originated. Limestone is mostly calcium with a bit of magnesium, certainly not a well-balanced soil. Glacial soils may have a soil from a mix of parent materials, which is consequently more balanced.

One of the reasons we want to know about our soil texture is because sand, silt and clay bring different fertility potential. Sand and silt have a limited amount of minerals in their composition that will become available to plants, and they can't hold onto other nutrients in the soil. Clay is made of many different elements, and the outside of most clay particles are covered in negative charges. Many other minerals in the soil - such as calcium, magnesium and potassium - are positively charged, so they attach to the negatively-charged clay.

Cation Exchange Capacity (CEC)

A positively charged mineral in the soil is called a cation. The cation exchange capacity of the soil basically refers to the ability of the soil to hold onto these positively charged nutrients like calcium, magnesium and potassium so they don't leach out. Roots excrete carbon dioxide, which combines with water to form carbonic acid and hydrogen. Some of the hydrogen knocks other cations off the exchange sites, which the plant can then take up. Note that CEC doesn't tell me how many nutrients I have, just the potential for holding them.

It's all about the clay, and specifically what kind of clay you have. For example, vermiculite clay is five to fifty times better at holding onto cations than kaolinite clay. We don't always know what kind of clay we have, but a soil test tells our CEC.

Nutrient Holding Capacity

Phosphorus, sulfur and some forms of nitrogen are often in the soil as negatively charged minerals called anions. Anions are not held on sand, silt or clay, but they are held by organic matter. Not only does humus have a spectacular CEC, but it holds onto anions, too. The cation exchange sites, the anion exchange sites, the organic matter, and the microbes contribute to the soil's overall nutrient holding capacity.

The pH discussion is covered in the full book. Here, all that needs to be said is that pH should genearlly be ignored. It's automatically corrected with organic matter and nutrients.

Organic Matter

Organic matter is anything that is living or was once alive. When looking at the soil, we're mostly referring to fallen leaves or needles and twigs, dead and live plant roots, and dead and live microbes. Compost is organic matter, too. Organic matter takes center stage when it comes to water-holding capacity and drainage, promotion of air in the soil and resistance to compaction, holding onto cations and anions, and providing fertility because it is made of nutrients and other substances. More high-quality organic matter in the soil generally means more beneficial organisms and fewer non-beneficial organisms.

Humus is organic matter that has been broken down by microbes so far that it resists being broken down any further. In the soil, humic acids are important chelators, combining minerals into organic compounds that are more available to plants. Humic acids will already be present in good soils with a lot of organic matter. Otherwise, they'll be lacking and it will be beneficial to bring them in as a supplement called humates.

Chapter 5
Soil And Plant Testing

The easiest test is to spend just a little bit of time getting acquainted with your soil firsthand. Dig a hole approximately 12 inches long, wide and deep. Try to take the soil out in big chunks if possible and place it in a wheelbarrow or on a tarp. First of all, how easy is it to dig? Look at the color of the soil. Dark brown is good. Pale beige, gray or blue is generally not as good. Smell it, too. Soil should smell pretty nice. It definitely shouldn't smell bad, like rotten eggs.

Determine your soil texture - the relative amount of sand, silt and clay in your soil. This information gives you a clue as to water and air conditions in your soil. It also gives you a hint as to its ability to hold onto cations.

Look at the soil you've taken out and make some notes about its structure. It takes some experience to do this, but it's really just a subjective, qualitative assessment of how your soil looks. A good sign is if the soil particles are aggregating together in some way, rather than staying separate like sand on the beach. You also don't want huge compacted clumps of clay.

Break up the remaining soil and count the earthworms. Earthworms are sensitive to their environment and chemicals, so if you have them it's a good sign. Ten per square foot is good, and 25 is great. You can also look down at your soil for other insects. If you have a mulch layer, peel it back and see what's living there. A magnifying glass helps with this. You may even be able to see fungal mycelium, especially around plant roots, and if you have nitrogen-fixing plants like peas and beans, you should be able to dig up a plant and find the tiny spherical nodules that house the bacteria on their roots.

Did you dig in an area where there are some roots? The deeper they go, the better. If they're stopping at a certain depth and growing sideways, there may be a hardpan there that we will slowly break up when we plant strong, tap-rooted plants and when we increase the organic matter content of the soil. A lack of fine root hairs in your soil profile indicates a lack of oxygen.

Soil Biology

If you're a food grower for market, you may want to know how many microbes you have in your soil and how diverse they are. You can get a microscope and learn to do some of this yourself, but for most people it's best to have a lab such as Soil Foodweb do it. At the time of this writing, it's about $60 USD for a basic test that covers bacteria and fungi, which is a good start. You can pay over $200 to include protozoa, nematodes and mycorrhizal fungi. Prices are currently double in their Canadian labs.

Then you can learn how to make specific composts and compost teas that select for specific kind of microbes, which I touch on in the compost tea chapter. I may do biology testing on a new garden if I know I'll be gardening there for awhile. Otherwise, I just go ahead and make the best compost and compost tea I possibly can, albeit not as specifically suited to the soil as it might be based on testing.

Plant Testing

There are a couple of methods of directly measuring the health of your plants with instruments. Just as with soil, before you get to more technical tests, it's very important to simply look at your plants and take some notes.

You can look for insect predators and diseases as indicators of plant sickness. A little more advanced, you can look for leaf discoloration that indicates certain deficiencies. I don't use this is my only means of determining deficiencies, because I think it's more complicated than that, but it's useful to compare these indicators with other plant and soil tests.

The main instrument test for plants is the brix test. It's one of the most exciting tests in our toolkit. It measures the dissolved solids in plant juice. Brix is a rather nice summary of how well we're doing with our soil management practices. When we balance the soil nutrient ratios, increase organic matter content, build our soil food web and so on, plants get healthier and brix goes up.

As your brix rises, your food tastes better, stores longer and is more nutritious. Very high-brix foods don't rot. They will slowly dehydrate, but stay nutritious and highly edible. They can stay good for years! Once you get the brix above a certain number, which varies for different plants but is often around 12, plant predators will diminish or go away completely.

We measure brix with a refractometer, which costs about $100.

The second reason we may test brix is more practical and useful. We can measure the brix in a leaf or especially a fruit from one of our plants, for example a tomato. We test the brix, then foliar feed that tomato plant, wait 30-60 minutes, and measure the brix again. If the brix has gone up at least a couple of points relative to a control plant that we also test, the tomato liked that fertilizer and we should spray the whole crop. If it stayed the same or even went down, the tomato might not want that fertilizer today. Even good organic fertilizers are sometimes not wanted by our plants.

Chapter 6
Soil Nutrient Testing

To get better information about our soil, we need to do tests. Most home kits are useless, so we want to go through a lab. Even then, the results we get back aren't even close to 100% accurate, but their usefulness has been proven by hundreds of soil consultants who have successfully used them to improve soils and crops.

When To Test

It's worthwhile to sample once a year in order to track long-term changes and continually work to move your soil towards the ideal. If you just want to do it once in year one and then forget about it, that's fine. Just make sure you don't skip doing it once. It's very important to sample at around the same time each year, under the same environmental conditions. Spring or fall is fine, the sooner the better. You don't want to sample during a drought or if you've applied fertilizers in the last month that supply high doses of specific nutrients.

How To Take A Sample For A Lab

You need only do one test, but you do want to combine at least 3 samples from different parts of your garden. If you're primarily interested in growing food, take 3 or more samples from your vegetable gardens and combine them. Most labs suggest your shovel should go down 6 or so inches to get a soil sample. You want to get soil from the surface down to whatever depth you're hitting.

When you're taking these samples, be sure to keep everything

very clean. The shovel should not be rusty. The pail needs to be sparkling clean and cannot have contained fertilizers. After the samples have been thoroughly combined in a pail, usually 2 cups are placed in a new, clean bag or container to be shipped to the lab. Some labs are happy with 1 cup. Most labs don't care if the sample is wet or dry.

Choosing A Soil Lab

While it may be tempting to drive a sample over to your local soil lab, it may not be the best option. Right now, most soil labs aren't doing a great job. They're still stuck in the same chemical mindset of soil management that the colleges are teaching. We just don't speak the same language.

Below are my two favorite labs. These labs are doing the kind of tests that I believe are most useful. Current prices are $50-$75. You can use another soil lab, just make sure they do Albrecht testing and/or Reams/Lamotte testing or similar:

Crop Services International - http://www.cropservicesintl.com
International Ag Labs - http://aglabs.com/

Base Saturation

The first main test we probably want to get done is called a base saturation test. It gives us an indication of the percentage of bases, or positively charged ions - calcium, magnesium, potassium and sodium, possibly aluminum and importantly, hydrogen - in our soil. The significance of the base saturation test is that it includes hydrogen, which makes things easier for us. William A. Albrecht perfected the use of the base saturation test. The ideal results are 60-75% calcium, 7-15% magnesium, 2-5% potassium, 0.5-3% sodium, and 10-15%

hydrogen, and a few percentage points of all of the other micronutrient cations, such as iron and copper. We don't know precisely why nature has settled on these numbers. What we know is that often, the closer the soil gets to these numbers, the healthier the soil and plants become.

On sandy soil, calcium goes down closer to 60%, magnesium up to 10-20% and potassium potentially up to 6-8%. This is because the magnesium and potassium help the sandy soil to bind together. The amount of each nutrient in your soil is not as important as having the correct percentages.

This test helps us determine what mineral fertilizers we will apply to build the base foundation of the soil in the long term. It's important to still look at what weeds you have growing to see if they are telling you what the soil test is telling you. You may have 75% calcium from your test, but your garden is full of grassy weeds that indicate a calcium deficiency. That's one reason why we do more than just the Albrecht test.

Along with the base saturation test, you may have some anions tested, such as phosphorus and the nitrate form of nitrogen. The numbers are not particularly accurate. There is a better nitrogen and phosphorus test coming up in the next section.

The Reams Test - My Favorite

This is the second test we do. The Albrecht test is good, but we don't want to stop there. Carey Reams developed a testing system to give you an indication of what your plants might actually get from the soil, even more so than the Albrecht test. I ignore the anions such as nitrate and phosphate from the base saturation test, but rely on them more from the Reams test.

The Reams test uses acids are more like those produced by plant roots, therefore the test reveals more about what the plant can actually get from the soil, regardless of how much of each nutrient is in the soil. You could be sitting on a bed of limestone that might show up as having a lot of calcium in a base saturation soil test, but a Reams test may indicate it's not available to plants. It won't say Reams test on the paper, but if you look for these numbers I have below all lumped together, you've found it. Reams settled on the following as being amounts to strive for in pounds per acre using his test:

Calcium 2000-4000
Magnesium 14% of calcium
Phosphate 400
Potash 200
Sulfate 200
Nitrate nitrogen 40
Ammonium nitrogen 40
Sodium 20-70 (ppm)

When you get a Reams soil test back from a lab, you can compare those numbers to these numbers, and they probably have even done that for you. They may use slightly different numbers depending on their methods and on your crop.

With this test, you're aiming for a 10:1 calcium to magnesium ratio, or 7:1 for grasses/grains and for very sandy soil. The lower the ratio gets below 7:1, the more potential for compaction and drainage issues, as well as poor microbial life and unhealthy plants. If you see grass weeds such as crabgrass, it's probably because it's come along to help with calcium.

You're aiming for a 2:1 phosphate to potash ratio, or 4:1 for grasses. The calcium to magnesium and phosphate to potash ratio are the most important to balance, so worry about them first.

Chapter 7
Removing Threats (Step 1)

Pesticides

Pesticides kill living things. “Cide” means to kill. The pesticide manufacturers tell us these poisons will be broken down by the microorganisms in the soil. This may be true if we have a healthy, diverse soil food web, but every time we or our neighbors spray, even those neighbors within hundreds of miles, we decrease the number of healthy, happy microbes until eventually, there are very few of them left to perform this function.

Many pesticides have have worked for awhile, but eventually, the predators figure it out and come back with a vengeance. This time the chemicals don’t work as well or at all. In the meantime, the pesticides have done a dandy job of terrorizing the soil environment, ensuring that weeds are the only plants that will grow there and that plant predators flourish.

We’ve already seen how microbes are vital to the very existence of the garden, so we know we don’t want to kill them. Plants are also hurt by pesticides to the point where predators are invited to dine. Animals - our fertilizers, our seed dispersers, our pollinators, birds, bees, butterflies and everyone else - are hurt, too. Nearly 100% of rivers in North America and probably the world have pesticides in them and the majority of wells do, too. Many lakes and rivers are unfishable.

Chemical Fertilizers

It’s important to note that many chemical fertilizers are potentially just as damaging to the soil as pesticides. They undergo chemical reactions in the soil that can produce acids with a

pH lower than 1.2 or bases with a pH above 11, both of which are extremely toxic to pretty much any living being. Even the fertilizers themselves, which are salts, either destroy or interfere with the cell walls of microbes, hurting or killing them. They kick minerals out of the soil. Oxygen is created during this chemical reaction and organic matter is burned up. Some fertilizers even include or form formaldehyde.

Chemical fertilizers are mostly nitrogen, phosphorus and potassium. Consistent applications of these nutrients at the expense of the dozens of others that are needed creates an imbalanced soil environment, not to mention the sewage sludge and toxic metals and all kinds of other garbage that are often included in the fertilizers as filler. Most of the nitrogen - and some of the phosphorus and potassium - leaches into our waterways causing all kinds of problems. These products are harmful to soil life, acidify the soil and deplete it of nutrients, cause compaction, burn up organic matter, pollute our water, and grow plants that invite predator damage.

Genetically Modified Organisms (GMOs)

GMOs are made by taking a gene from one organism and firing it into the DNA of another organism along with a virus or bacteria to help the gene infect that DNA. *Bacillus thuringiensis* is a bacterium that produces a substance toxic to some insects, such as caterpillars. It has been used as a biological insecticide since the 1920s, and is now used to make Bt cotton, Bt corn, and Bt potatoes, which are genetically-modified crops. Research shows soil microbial life and beneficial enzymes decrease when Bt crops are planted. One study concluded that soil life could be entirely dead after 10 years under a Bt crop. Another study found the gene in GM corn was passed to various soil organisms.

The list of other potential problems is long. Altered genes get into our waterways where they may affect aquatic life. They may impact beneficial insects in our garden. Because genes can and do jump from one organism to another, they contribute to herbicide-resistant weeds. The general consensus among organic gardeners is that we should avoid using any GMOs in our garden because we don't know the long term effects, and because there is absolutely no reason we need to use them in the first place. This means not only that we don't plant GMO seeds, but we don't use alfalfa meal, canola meal, corn gluten meal, cotton meal, soy meal or any other plant fertilizers unless we're absolutely sure they are non-GMO.

Soil Contamination

Some soils, especially in urban environments, are contaminated with various toxins and heavy metals. Many of the chemical and physical methods of reclaiming polluted soil require a lot of energy and often leave the soil lifeless and unproductive. Some methods go so far as to remove the soil and treat it as hazardous waste. Another approach is to work with nature by using microorganisms (bioremediation) and plants (phytoremediation) to help with the process. Though it takes longer, these actually improve the soil, while chemical and physical processes can be very destructive.

Fungi are especially adept at breaking down hydrocarbons such as those found in oil. Certain plants can pick up nearly all of the heavy metals from a soil. They can then be harvested and disposed of elsewhere. Admittedly, this process just moves the problem elsewhere, but that's the way it is with minerals. They can't be broken down like organic molecules. I believe testing for and fixing contamination is very important. After doing some research, it seems it's more important than I had previously considered.

Chapter 8
Water (Step 2)

While perhaps not as exciting as say, the latest fertilizer or microbial inoculant, water is more important. Water is essential to life. Not only do we drink it - we are made of it. We know our plants are made of water, too, and they need it for photosynthesis and cooling. What is often overlooked is that all living species in our garden need water. Sure, it's a great idea to provide a water source for birds and other animals, but I'm referring here to the soil life. Insects, earthworms and microbes all need water.

Our Water Supply

Aquifers around the world are drying up, including in the U.S. and Canada. Half of the wetlands around the world have been lost since 1990. At least a third of rivers and streams in the US are so polluted that fish are inedible and swimming isn't safe. Lakes are worse off. The majority of wells have pesticides and even more of them have pharmaceuticals and other man-made toxins.

Substances like fluorine, chlorine and chloramines are put in our water in an attempt to clean and improve it. Some of this is unnecessary and harmful to us. None of it focuses on the root cause of the problem, which is the absurd chemicals we shouldn't be producing and disposing of in the first place. Even in rural areas, our wells are contaminated.

To protect our water, we can start by not using pesticides, chemical fertilizers and genetically-modified products. We can also establish a garden that is teeming with plant and microbial life in order to clean up toxins and pollutants. There are

certain microbes that specialize in doing just that, such as the *Rhodopseudomonas palustris* found in EM.

Collecting Rainwater

Before we look at irrigation, let's first look at how we can save water. I find it interesting to actually run the math and see how little water rainwater barrels hold. If your roof is 1000 square feet (93 square metres) and you get 1 inch of rain on a spring Friday afternoon, you'll have 625 gallons of water coming off that roof. A 60 gallon rainwater barrel will fill up, but 90% of that water is going elsewhere, maybe into your city's storm drain system.

A 600 gallon rainwater cistern could handle almost a full inch and a 1500 gallon cistern could easily take 2 inches. Think of it as a giant rainwater barrel. Ideally, almost every house would have one of these, the size dependent on the amount and seasonal patterns of rainfall in your area. If you don't like the sight of them, they can be cleverly hidden or even buried.

The thing is, they can be expensive. A more attractive and potentially less expensive solution would be to build a small pond, bog or rain garden into which you can direct the roof water. A pond the size of a king size bed and 4 feet deep should hold an inch of rainwater off the roof.

Rain Harvesting Into The Soil

We should mostly be focusing on the ultimate storage solution, the soil. A loamy sand without organic matter, which is 70-85% sand, hence not very good at holding water, can hold at least 2 inches of water. Of course, just how much depends on how wet it is already, the health of the soil food web, com-

paction and so on. This loamy sand could potentially store that inch of rain, plus the extra inch from our roof, if we could somehow direct that inch evenly over 1000 square feet, which we probably can't, and if the infiltration rate of the soil is high enough, which it may or may not be.

Soils higher in silt and clay can hold 4-5 inches of water, but infiltration rates on these soils are generally much lower than 1 inch of rain per hour, so they may have enough to handle with the rain alone, unless it comes gradually over a few days. So what to do?

There's one thing we can put in and on our soil that will hold the extra water, and that is organic matter. Various research has tried to determine how much water organic matter can hold, often concluding it can hold tens or even hundreds of times more water and nutrients than the same amount of soil. Even if it holds only 4 times its weight in water, you can hold nearly an extra inch of water if you can increase the organic matter content of your soil by 1.5%, easily doable.

Organic matter can be brought in via compost and mulch. Even incorporating 2 inches of good compost into the top 12" of a new garden bed will often increase the organic matter content by 2-3%. It won't increase the stable humus that much, but I'm just talking about any organic matter here. Mulch goes on top of the soil, but it holds a lot of water, as well. Your soil should always be covered in mulch, and when possible, plants. This improves water infiltration and decreases evaporation.

Drip Irrigation

Drip irrigation was developed to save water by dripping it directly to the roots of plants, rather than spraying the entire landscape. It was designed for farming in very dry climates

where water is scarce. It's mostly inappropriate in most residential gardens for 2 reasons.

With the frequent, shallow watering of drip irrigation, the majority of the roots will tend to stay right by the plant instead of reaching further into the soil for water and nutrients. The rest of the soil needs water just as much as the plant because the microorganisms, earthworms and insects need water, not only for their own health, but also in order to give the plants nutrients, water, a healthy organic soil environment, and protection from plant-feeding organisms. Remember, plants get all of these services from the organisms in the soil. Drip irrigation may save water in the garden, but at the expense of the plants we're trying to grow and that once grown would actually attract water into the landscape, sequester carbon, produce oxygen, feed bees, butterflies and other animals, and cool our houses and cities.

Providing The Right Amount Of Water

I recommend irrigating with anything that provides water to the entire landscape: by hand, with a sprinkler, microspray heads, or even soaker hoses if they overlap enough, although the latter really only have occasional usefulness. Evaporation is negligible. I do this in the morning.

It's difficult to determine exactly how much water to apply. For home and market gardeners, I prefer to go by feel rather than do complicated calculations. You want to water deeply to encourage the roots to go down, and then allow some time for the soil to partially dry out, but not entirely. It should be thoroughly wet after you water it, but not to the point of run off. Even though you should water more deeply, less often, your mulch layer should generally stay good and moist.

Chapter 9
Organic Matter (Step 3)

Step 3 comprises four chapters. Despite some claims, plants and microbes really do care about the source of their nutrients. They prefer and often do better with organic forms of the elements instead of synthetic chemical forms. In the last century, we've burned up more than 90% of the organic matter in many of our soils. Humus is our ultimate goal, but we also want a supply of fresh organic residue as food and shelter for microbes and animals. As this residue is broken down, carbon dioxide becomes available to plants. Conventional agriculture has largely ignored organic matter, and organic gardeners have relied on it perhaps too much at the expense of other management practices.

Mulch

Thick, dense mulching in the garden with the right material provides a huge array of benefits. Not only does it smother weeds both physically and sometimes biochemically by tying up nutrients on the soil surface, it makes the ones that do find their way through so much easier to pull. When we mulch, we create homes for insects and other animals and provide them and microbes with food. They take this food and turn it into available minerals and humus, incorporating it into the soil to create amazing soil structure. Then all of the other benefits of good organic matter begin to accrue - increased CEC, water-holding capacity and fertility, and decreased compaction.

Mulch is often applied 2-3 inches thick, kept away from tree trunks, which don't want to be covered in anything.

Landscaping Fabric

Unfortunately, landscaping fabric can stop air and water from getting down to the soil. But the biggest problem with this fabric is that it doesn't allow organic matter to recycle into the soil. When you put landscaping fabric on your garden, it means your soil doesn't get to eat anymore. This is definitely not an appropriate mulch, except under pathways. Putting landscaping fabric in the garden stops all of this and slowly kills the fertility and structure of the soil, and everything living in it.

Stones

Stones and gravel provide some benefits in that they protect the soil from erosion and decrease evaporation, but they don't breakdown into humus and don't allow organic matter to get down to the soil, so they don't do much to improve soil health.

Peat Moss And Coir

Peat is not useful to us a mulch, and is relaly not very useful as a soil amendment either. Compost is better. Peat bogs are unique, vitally important ecosystems for this planet. When they are harvested for their peat or to create farmland, these ecosystems are gone, species go extinct, and a huge amount of greenhouse gases are emitted. The bogs are supposed to be restored after harvest, but many aren't.

Coir is ground coconut fibre, a by-product of the coconut industry. It doesn't have the high CEC of peat, but it also doesn't have the water and pH problems. There are sustainability issues with coir, too. Most of the coir you see in your garden centre is coming from far away.

Bark Mulch, Wood Chips And Sawdust

Bark mulch and wood chips are some of the most commonly used mulching materials in the garden. They satisfy many of our mulching goals, but unfortunately, they have a couple of potential problems making them one of the mulch types I don't generally use.

Bark contains oils that repel water and wood chips can become hydrophobic, preventing water from getting through to the soil. Bark in particular is low in nutrients, so it doesn't improve soil fertility as much as other mulches. Conifer bark such as cedar and fir can be high in toxins. Wood, including both chips and sawdust, is very high in carbon and very low in nitrogen. This means microbes have to pull much of the available nitrogen from the surrounding area in order to break down the wood, which can end up causing a nitrogen deficiency in your plants.

However, if you have shrubs and trees that like a fungal environment, wood chips will promote that, especially if you don't over water. If they are coarse wood chips and if you put just a couple of inches and leave them on the surface without digging them in, the nitrogen shortage may not be a big problem. Wood chips from the non-bark part of the tree and even sawdust can have some good nutrition in them, so they're a great addition to composts where they can be properly mixed with nitrogen materials.

Straw, Hay And Grass Clippings

Straw and hay aren't the most aesthetically pleasing, but they are fairly good mulch types. The difference between straw and hay is that straw is just stalks from harvested grain, while hay is finer and has seeds, so it will often actually produce

weeds. You can deal with this by composting it in a hot compost to kill the weed seeds. Grass clippings aren't the best mulch to use in the garden in abundance because they can get so tightly packed together that they inhibit air circulation. Besides, they're far too important for the soil of your lawn to bring into the garden.

Leaves

Of all the mulch types, by far the best is leaves. They do absolutely everything right. If you don't have enough leaves, your neighbors will usually be happy to give you theirs, since they would otherwise have to rake them up and dispose of them. Ironically, some organic gardeners give their leaves to the city in the fall and then pay a fortune to buy them back as leaf mold in the spring. Leaf mold is just leaves that have been slightly decomposed. It's one of the best mulch types, too, but in most cases, the gardener would have done much better to save the money and keep the leaves in the garden over winter where they can protect the soil.

Some people think leaves are not one of the most attractive mulch types for the garden, but is a forest floor unattractive? We've been conditioned to think that bark mulch or bare soil is the most aesthetically pleasing, but if you cover your garden in a rainbow of autumn leaves, I think you'll see it differently. When we remove the leaves, we are breaking nature's cycle and creating more work for ourselves.

I know someone reading this is wondering about oak leaves. I've never had a problem with the fact that oak leaves don't break down quickly. I've always enjoyed that about them because it just means my mulch stays around longer. And nope, they don't acidify the soil to any notable degree, but again, if you have too many, don't force it.

Chapter 10
Compost

Compost is our way of mimicking nature, yet speeding it up substantially. We add compost to our soil to quickly increase the number and diversity of microbes and small animals, organic matter content, and nutrients in our soil, all of which are often low because of past gardening or other land use practices. It's better to concentrate your efforts on one properly managed pile than many, poorly managed piles. As you'll see, you actually need very little compost to get big benefits.

Materials

Pretty much anything that was once alive can go in there. The more variety in your raw materials, the more diverse the resulting compost. As previously mentioned, I don't use any GMO materials. The 3 most important ingredients in compost are plants such as leaves, weeds, grass clippings, and straw; manure; and food scraps. Useful supplementary materials include newspaper, cardboard, wood chips and sawdust.

There are dozens of other materials out there. Some of them are available only in certain regions. You may not have enough stuff on your property to keep a good pile going. For this, get food scraps from your friends and neighbors and offer to take their leaves in the fall. Find a farm or orchard with some spoiled hay or fruit. While you're out there, find a source of animal manure from a farm or stable.

We loosely categorize our materials as being carbon materials and nitrogen materials. Carbon materials tend to be yellow-brown and dry, so they're sometimes referred to as "browns". They can have anywhere from a 30:1 carbon to nitrogen ratio

to hundreds of times as much carbon as nitrogen. Nitrogen materials tend to be wet and often green, so they're sometimes called "greens". Despite the name, they still have more carbon than nitrogen, but the ratio is generally much lower - between 10:1 and 30:1.

Carbon materials include leaves, straw, hay, paper/cardboard, and wood/sawdust. Nitrogen materials include manure, seaweed, grass clippings, alfalfa hay and food scraps, although manure varies depending on the animal and the freshness. In reality, all of these materials vary based on different factors.

Other Materials

Experts also say not to compost diseased plants, but I disagree. First of all, most pathogens will be killed in a well-made pile, and perhaps more importantly, their predators will be given a reason to flourish if their food source is around. We need some disease around in order to keep the predators that eat that disease around, so I put all diseased plants right into the pile. About the only things I don't compost are toxic materials such as colored paper and carpet, and noxious weeds such as quack grass and bindweed that may survive the composting process and be subsequently spread throughout the garden. But yes, I use oak leaves, pine needles, cooking oil, ashes, and even a small amount of meat in the middle of the pile.

Activators

Activators are extra substances that stimulate the composting process. Some of the potential benefits of using activators are less time until the pile is finished, a better finished product and less odor. Some activators such as clay, humates, calcitic lime and gypsum also decrease nutrient loss from the pile, espe-

cially nitrogen, which is a big deal.

When I'm building a new pile, I inoculate it with finished compost, generally as much as 10% of the pile or even just a few shovels if that's all I have. I'll also add as much as 5 pounds of humates per yard of raw materials, although that can get expensive. I use as much as 10% clay in the pile. You don't want to add clay directly to sandy soil, but composting it gives it a chance to form a clay-humus complex. Bags of bentonite clay are great, or even just a clay loam works well.

I'll cover effective microorganisms (EM) and biostimulants later in the book, but I will mention here that inoculating the compost with EM will speed up and improve the process. Odors are also greatly reduced. Rock dust is an incredible addition to the compost. I use 20 pounds.

Products such as calcitic lime and soft rock phosphate will bind with the organic matter. In fact, even without a soil test, it would be entirely appropriate to add 5 pounds of calcitic lime per yard of raw materials when building the compost, as it is so crucial to the microbes in the pile. Alternatively, 5 pounds of gypsum works well to get things moving, perhaps because of the sulfur. Urine is exceptionally good, admittedly a bit easier for guys. Penergetic is a homeopathic product that helps stabilize the composting process and bind nutrients.

Manure

It's a bit of work for city folks to find manure, but it does play an important role in the compost pile for its nitrogen content and microbe population. That being said, I've spent the last few years as a vegetarian and a vegan, and certainly support using no manure if you prefer. Composting manure helps with many of the problems associated with applying it to soil. For

many reasons, we want organic manure.

Buying Compost

Many gardeners will prefer buying compost from a garden centre or the municipality. It should smell good, not like garbage. Ask about the raw materials. Is there toxic paper mill waste or household waste, or pesticide-laden grass clippings? Don't use compost that has been made with sewage sludge.

Using Compost

The best time to apply compost is in the spring and fall. In the spring, I apply it at least two weeks before planting. If I'm using compost to make a new garden bed or install a new lawn in a soil without much organic matter, I'll often till 2-3 inches of compost into the top 8-10 inches of soil. For maintenance on existing beds, I'll apply between 1/8 inch and 1/4 inch to the surface. I may lightly incorporate it, but I don't do much tilling for maintenance. For an existing lawn, you can screen out sticks and big clumps and apply it at 1/4 inch thick.

The Luebke's in Austria recommend 10-12 tons per acre to start and then down to 3-8 tons for maintenance. Elaine Ingham recommends1-5 tons per acre for maintenance. 12 tons per acre is only about 2/5 yard of compost (1/8 inch thick) per 1000 square feet and 1 ton per acre is only about 7 gallons of compost (1/90 inch thick) per 1000 square feet. When planting trees and shrubs, rather than backfilling the hole with compost, amend the entire planting area at least twice as wide as the planting hole by incorporating compost into the soil. We want to enrich the soil, but we don't want to make the planting hole so rich that the roots don't leave it.

Chapter 11
Making Compost

There are many composting methods, but the most common is probably the outdoor, above-ground compost pile. An enclosure can keep out critters, prevent the pile drying from wind and look a little more tidy. It can be made of used wood pallets or fresh wood, concrete blocks or anything else that holds the compost in place. Some gardeners have two or three such enclosures for different stages of the pile, such as raw materials, in-process compost, and finished compost. The microbes do the work. All we need to do is construct the pile to have the correct air, moisture, temperature and carbon to nitrogen ratio.

Air

Oxygen is important because we're making aerobic compost. There are two basic methods to ensure there's enough air, and you can use either or both. The first is to put a layer of brush, branches and sticks on the ground under the pile that is at least a few inches high. The second method is to turn the pile over once in a while. For the fastest decomposition, this is done whenever the pile starts to cool down from it's hot phase, usually every 3-7 days. Even turning a pile once each season is helpful. In fact, when I'm not in a hurry, this is what I do because while an unturned or little-turned compost pile takes longer to finish, it retains more nutrients.

If you don't want to turn, but need your compost to be done more quickly, you can put perforated pipe into the pile both horizontally and vertically, or even just put some poles vertically into the pile that you can pull out after the pile is made. You can use ABS pipe if you're concerned about toxic PVC.

The fastest way to get it done, however, is to turn it regularly. A “hot” compost pile can be largely done in 2-4 weeks. Most weed seeds and pathogens can be killed in this time. A slow compost pile has big advantages. Not only does it retain many more nutrients, but research shows it’s more able to suppress disease, probably because more beneficial microbes survive the composting process, especially fungi. We can also allow the pile to go through a maturation phase, where it’s already looking like finished compost, but sits for another perhaps 6 weeks at a cooler temperature allowing many microbes to multiply. This curing time is vital to make the best compost.

Moisture

A compost pile should be moist like a wrung-out sponge. This means when you take a fist full and squeeze it, it should feel wet but not drip water. This is somewhere between 30% and 70% moisture, with 50%-60% generally considered ideal. If it’s too moist, it can turn anaerobic and promote the wrong microbes, as well as leach a lot of nutrients. If it’s not moist enough, decomposition will be very slow, but this is a better problem than too much moisture, which takes more effort to fix.

If the pile gets too moist or if it starts to smell bad, you can take it apart, air it out, and then add more carbon materials when you put it back together. If it gets too dry, water it and perhaps apply more nitrogen materials. You may need to take it apart here, too, in order to get it sufficiently wet.

Temperature

Different studies have come up with different ideal temperatures, but it’s generally agreed that 130-150F (55-65C) for

several days is adequate. If you're judging with your hand, it should be too hot in the pile to keep your hand there for long. Ideally, it would be allowed to finish for 6 weeks at cooler temperatures. Still, significant reductions in pathogens have happened when the compost pile never went above 104F (40C).

To get the higher temperature, the pile should be at least 3 by 3 by 3 feet as a bare minimum, and as much as 5 by 5 by 5, although some people go 10 feet wide. For the most part, the more frequently a pile is turned, the hotter it tends to get and the hotter it stays, although the most important part of reaching high temperatures is the right amount of moisture, proper pile size, and balanced carbon to nitrogen ratio.

Carbon to Nitrogen (C:N) Ratio

If a pile has too much nitrogen, it may go anaerobic, create bad compost and smell awful. If the pile doesn't heat up, you may need to add more nitrogen materials. The ideal carbon to nitrogen ratio of a new pile is somewhere between 25:1 and 30:1, by weight, not volume. The way to get this ratio is to use between 2 and 4 times as much carbon materials as nitrogen materials. By the end of the composting process, the ratio in the pile goes down to somewhere around 10:1, because carbon is released as carbon dioxide.

Building The Pile

There are many variations on how to build a compost pile. Here is how I do it, step-by-step. This is for a 3 by 3 by 3 foot pile. Make sure your hose can reach it. I build my pile all at once in order to create the best possible pile. I tend to use manure, kitchen scraps, leaves and straw as my basic materials, along with whatever other organics I can get, such as waste

from a brewery, orchard or winery. The composting process will be much faster if big materials are shredded or chopped, but if chopped too fine, the pile will go anaerobic.

I build my pile right on the ground to invite earthworms and other soil insects up into it. I water the ground first and put a base layer of branches and brush 3 feet wide and long. Some people like to build in layers. I just take turns putting carbon- and nitrogen-rich materials into the pile. I usually put 2 or 3 shovels of carbon material for every shovel of nitrogen material. If you have neighbors who are intolerant of any odor, you can use 4 shovels of carbon material to be safe. I may also try to have a carbon layer on all sides of the pile to control odor and discourage animals and flies from hanging out around the compost.

I occasionally sprinkle in my activators throughout this process, and hit the pile with some water every once in awhile. I top it off with a layer of leaves or straw and tarp it during the rainy season or the sunny, hot season to decrease evaporation. If I'm in a hurry, I turn this pile every 3-7 days. Otherwise, I turn it every 3 months or so, except winter. I may put food scraps into the inside of the pile once a week, adding some carbon material at the same time. If the compost isn't working or smells bad, it could be the wrong moisture balance, not enough air, too small size, or an improper carbon to nitrogen ratio.

Sheet Mulching

Sheet mulching is kind of like composting right in the garden, mostly to create new garden beds and in existing vegetable beds during the fallow season. The ingredients are the same. It's covered in detail in the full book.

Chapter 12
Indoor Composting

Bokashi

Bokashi is a fermented substrate such as rice bran or wheat bran, but it can be made with many other kinds of waste materials such as sawdust and other grain scraps. It's fermented by mixing it with EM. It has many of the same benefits as compost, but the process is a fermentation, without air, like making wine or pickles. Bokashi is made by filling a container such as a 5 gallon pail approximately two-thirds full with the substrate in order to leave room for stirring. Then you make a mixture of EM, molasses and water, generally at a ratio of 1:1:100, which is 10mL each of EM and molasses per liter of water. In this liquid, you can optionally mix liquid kelp, fish, and/or sea minerals.

You then press the mixture firmly down to get the air out and cover it with a plastic bag and then a plate, and even a weight if you have it to keep the air out. We want this to ferment without air for 1 or 2 weeks, therefore no more stirring is done from now on. It's better if you can keep it warm somehow, around 100F. Otherwise, it may take a few weeks, which is fine.

When it's done, it should have a pleasant sweet and sour smell, kind of like pickles. If it smells really bad, something went wrong. It's alright to have some white fungi, but you should not see fuzzy green or gray molds. Once your bokashi is finished, you can put it in the garden or store it in a cool, dark place. If stored anaerobically under the same conditions as it was made, it will keep many months, and can actually improve with time. If dried and then stored, it will keep for at least 2 months.

The bokashi can then be used as an incredible way to inoculate your soil with these beneficial microbes. The 2.5 gallons left in that pail will inoculate 500 square feet of garden. While bokashi is traditionally a good way to make use of waste materials, it is now often dried and used in the kitchen to help pickle fruit and vegetable waste. Every time you put the waste into a waste bucket, a small handful of dried bokashi is sprinkled on top. Odors are controlled extremely well. When the waste bucket is full, you can bury the waste in the garden or compost. It will break down extremely fast.

Worm Composting

Compost made by worms is called vermicompost. The worms dine on the food scraps largely to get the microbes covering the surface. I use a plastic storage container that's approximately 18 inches wide, 24 inches long, and 12 inches high, with a lid. This size easily allows for the 4-5 pounds of food scraps I need composted each week, perfect for 2 people.

To make your bin, drill 12 holes approximately 1/2 inch in diameter in the bottom and at least as many holes towards the top of the sides. Some people also like to drill holes in the lid. The holes allow for air and water vapor exchange, with the bottom holes also facilitating drainage. You'll need something underneath the bin to catch the water that drains out.

The materials are basically the same as a regular compost pile. I don't use meat, dairy or oil, and the worms also don't like too much citrus or salty food. Since your food scraps are your nitrogen materials, you'll need to supply some other forms of carbon materials as bedding. I use a mixture of shredded newspaper, leaves and straw. A handful of sand (or soil containing sand) is also needed for the worms to be able to digest food properly. 1/3 cup of calcitic lime per cubic foot of compost

will probably be helpful for the calcium.

Just like a compost pile, your bin needs to have proper air, moisture, temperature and carbon to nitrogen ratio. The bedding should be wetter than a compost pile - 70%-90% moisture. It takes about three times as much water as bedding to get it moist enough. The temperature should be between 60F and 80F, out of direct sunlight. When the bedding mixture is thoroughly moistened, you can add your red wiggler worms, *Eisenia fetida*. Start with the most common recommendation - 1 cubic foot of bedding and 1 pound of worms. I gave them 1.5 pounds of food scraps per week at the beginning. Now that the worm and microbe populations have multiplied, I give them 4-5 pounds per week.

After 3-6 months, you'll want to stop adding food scraps for a couple of weeks to let the worms really break down what's already there. Then, to use the finished compost, you need to separate it from the worms. I've used two methods. The first is to move everything into one half of the bin and start new bedding and food scraps in the other half of the bin. After 2-4 weeks, most of the worms will have migrated to the new side of the bin to get at the new food. You can then harvest the finished compost. The second method of harvesting is to empty the entire contents of the bin onto a tarp or garbage bag under a bright light. Worms don't like light, so they'll try to stay buried at the bottom of the pile. You can separate the compost.

If many worms are exiting the bin, something is wrong. It may be too moist or not moist enough, or there may not be enough air. It may be that the compost is done. The castings are slightly toxic to them, so they don't want to stay around long when the food has run out. In rare cases, you may find the worms aren't eating the food or are rolling up together in a ball. It usually comes back to a problem with the oxygen, moisture, temperature, or carbon to nitrogen ratio.

Chapter 12
Cover Crops

A good goal is to make sure your soil is always covered with plants, and cover crops help achieve this goal. The main reasons home gardeners use cover crops are to improve soil fertility, increase organic matter and control weeds and plant predators. There are also many other uses, such as to prevent erosion, send deep roots to break up compaction, conserve moisture and increase water infiltration, attract insects and other animals, and even provide food for humans and animals. Let's look at the three main reasons.

Cover crops improve soil fertility in a couple of ways. The main benefit most people think of is the increase in nitrogen we can get from planting legumes, such as clover. Fertility is also improved by many cover crop plants that send deep roots into the soil and harvest minerals that aren't reached by other plants.

The next main benefit is organic matter. Cover crops are often turned into the soil to give a huge influx of biomass. Less talked about, but potentially more important, plants send a huge amount of carbon - as well as protein, amino acids and thousands of other substances - into the soil as exudates. Along with this is microbial biomass. Without plants, many microbes will go to sleep, but if we keep plant cover they'll keep working, even through winter, albeit more slowly.

And then there is weed and pest control. Plants accomplish weed control by several mechanisms - competing for water and nutrients, shading out the soil, crowding out the soil below ground with their roots, and sending out chemicals to inhibit other plants from growing. Plant predator control is achieved mainly by the cover crops inviting and hosting a diversity of

microorganisms, nematodes and insects that keep the system more in balance, as well as producing antibacterial compounds.

Legumes

Most of our nitrogen-fixers are from the legume family, working with *Rhizobium* bacteria. The root encircles the bacteria colony and creates a nodule as big as a kernel of corn where the bacteria live. The bacteria make an enzyme that converts gaseous nitrogen to ammonia and the plant uses that ammonia to build amino acids. In return, the plant gives carbohydrates and other organic substances to the bacteria. It's a very good idea to add the bacteria in with the seed or buy seed that has already been inoculated. The two main forms of inocula are solid and liquid, with solid being the most common. Either of them can be mixed with the seed before you plant or applied in the furrow directly to the seeds.

Even though they're planted earlier than grasses in the fall in order to get them established before winter, legumes don't do much until spring, when they put on their growth and fix most of their nitrogen. Most of the nitrogen fixed by a legume isn't released to other plants until the legume decomposes. What we often do, therefore, is cut the crop down right in the early to mid stages of blooming in the spring before we seed or transplant our vegetables. Legumes also contribute to an increase in organic matter and weed control, although not as much as grasses. Also, since they break down much faster than grasses when you knock them down, due to their relatively higher nitrogen content, they don't provide a long lasting mulch. The positive side of that is that they do release their nutrients more quickly to plants than grasses.

Grasses

Grasses are used when your main goals are creating a lot of organic matter, controlling weeds, and taking up nutrients - especially nitrogen - from the soil so that they don't leach. Grass will do a better job than a legume of keeping a lot of that nitrogen rather than allowing it to leach, and also acts as an excellent weed control and huge organic matter builder.

Grasses have a higher carbon to nitrogen ratio than legumes, so they break down more slowly, acting as a longer term mulch. The longer breakdown period of grasses also means the nutrients will not be as immediately available to the next crop. Winter annual grasses are seeded in late summer or autumn. They grow before winter, go dormant during winter, and grow again in the spring before we usually cut them down.

Companion Plants And Polycultures

Companion planting in a vegetable garden involves pairing plants that work well together. Examples are green beans and strawberries, carrots and tomatoes, and lettuce and spinach. Sometimes the plants simply work well together because they take up different areas above or below the soil. Sometimes one plant deters a predator of the other plant.

A polyculture involves planting many plants together to take advantage of various niches in the garden, much the way nature fosters this diversity. Some will grow tall and provide shade, while others hug the ground. Some are ready for harvest early, while others take longer, even within the same food group, such as lettuces or tomatoes. Some attract beneficial insects, while others repel plant predators. Some provide nitrogen for the soil, while others happily gobble it up.

Mixtures

Rather than choosing one, I mix grasses and legumes in order to get the benefits of both. By planting them together, there is a much greater chance that at least one or two of them will do well in your soil and climate conditions. Gardeners and farmers use all kind of plants as cover crops: dandelion, fava beans, fennel/dill, yarrow, and even parsley, but I recommend you start with the most common: hairy vetch, clover, cereal rye and annual ryegrass. These are covered in the full book.

How To Seed And Care For Cover Crops

Cover crops are just plants. They're cared for much the same as other plants. If you're using them in a vegetable garden in the fall, they should be seeded right after your main harvest time or even a week or two before your harvest. Of course, many of us grow a mixture of vegetables that we continuously harvest, and in that case we just plant the cover crop towards the end of the season. I like to plant fall cover crops a couple of months before frost to get them firmly established.

If possible, it's best to get seeds into the soil. Small seed legumes go about 1/4 inch deep while larger seed legumes and small grains are planted 1 to 1.5 inches deep. While generally not as successful, you can broadcast the seed for small seed legumes on the soil at a higher rate and you should get germination if you keep the soil moist for the next week.

You'll probably be cutting down your cover crop before you seed or transplant. You can just use a hoe or various other tools. It's generally a good idea to wait 2-3 weeks before you seed and 1 week before you transplant, to reduce allelopathy and potential predators and allow some nitrogen release from the plants.

Chapter 14
Microbial Inoculants (Step 4)

We generally need more microbes. Remember, microbes make our soil healthy, feed and protect our plants, and clean our water. They even help to control weeds, insects and diseases just by improving the health of the soil. Fortunately, there are some quick ways to inoculate our gardens with microbes, and an additional benefit of these methods over compost is that we can apply some of these not only to soil, but directly onto the leaves. There are new ones being developed all the time, but there are three I use regularly. Two of them - compost tea and effective microorganisms (EM) - deserve their own chapters, which follow. The third, mycorrhizal fungi, is below.

When to Use

All of these inoculants are best used during the growing season, especially during certain times of year - planting, high-stress situations, disease-prone times and spring and fall when microbes can most happily flourish. It's best to apply them in the morning or evening when there is a lower solar index or on a cloudy day, but this isn't essential. It's also ideal to apply right after rain or irrigation and after mowing for turf.

If possible, compost tea and EM are preferably applied in relatively frequent, smaller doses, such as on a monthly basis, and weekly during stressful periods such as during disease season on grapes. If using spraying equipment, you'll want to filter the compost tea and EM to get out any rock dust and other solids that are used during the brewing process. I always like to apply microbial inoculants along with other biostimulants such as sea minerals, kelp, fish, humic acids, and

molasses, or even multiple inoculants at the same time.

Indigenous Microorganisms

If you have a forest nearby, taking a few handfuls of soil and putting it into your compost pile or even into the garden will bring in some different microbes. A meadow or aquatic system will have yet other microbes. This is a simple, effective way of increasing microbial diversity.

Even more fun, we can culture our own microorganisms. Rinse a small amount of rice and pour that rinse water into a container, leaving the container 50%-75% empty and putting on a loose lid so that air can still get in. Keep the container at room temperature out of the sun for 7 days. Once you see a thin film on the surface, strain the liquid into a bigger container and add 10 times as much milk. In another week or so you may have some solids floating on top that can go into the soil or compost, and a clear, yellow fluid underneath that contains the bacteria. Separate this fluid into another container and add an equal amount of molasses to keep the bacteria fed. Store it in the fridge until you're ready to use it. Mix it with 20 parts non-chlorinated water and spray it on plants, soil and compost.

Mycorrhizal Fungi

Over 95% of plant species form symbiotic relationships with mycorrhizal fungi. The fungi provide nutrients and water to their host plants in exchange for carbohydrates and other goodies. In fact, plants will trade as much as 80% of their carbohydrates with these fungi and other microbes. Mycorrhizal fungi greatly improve soil characteristics, and are among the most important microbes that form relationships with plants.

We can inoculate our plants with mycorrhizal fungi by taking just a small bucket of soil from a healthy environment that contains the right fungi, or by buying a product from a garden centre or online. While the first method sounds like more fun to me, I've always gravitated to the second because I know what I'm getting.

There are two main categories of mycorrhizal fungi. Over 90% of plants form relationships with endomycorrhizal fungi, also called arbuscular mycorrhizal (AM) fungi. You need them for most of your vegetables, grasses and many ornamentals. About 5% of plants, including many conifers and some deciduous trees, form relationships with ectomycorrhizal fungi. When you're planting a mix of plants, you can often buy a mixture of endo/ecto fungi and just use that for everything.

Applying when you seed and plant will allow you to establish contact between the fungi and plant roots, which is important because that's where the relationship occurs. There's no benefit to foliar feeding with mycorrhizal fungi, as they need to touch the roots. We can, however, mix them with biostimulants before application. This inoculant shouldn't need to be applied more than once.

Rub the fungi directly on the root ball if possible, or sprinkle in the planting hole. For seed, mix it dry with the seed before spreading. While not as good, the other choice is to apply the product to existing landscapes. The powder form is best for mixing with water to get the spores to infiltrate into the soil. For turf, it's better to do this right after aerating so more of the spores get down to the roots. Otherwise, it can be watered in. *Trichoderma* is another kind of fungi that is receiving a lot of attention. They aren't mycorrhizal, but they colonize plant roots, improve plant growth and are especially noted for controlling nearly all types of soil diseases. They can be purchased as an inoculant, as well.

Chapter 15
Compost Tea

There's a new compost tea game in town that involves bubbling air through the water with some kind of air pump and adding specific foods to feed and multiply the microbes, and that is now called compost tea. The new system can extract and multiply an astonishing number and diversity of beneficial, wide-awake, aerobic microbes. One of the reasons we do this is to inoculate our soil with microbes when we don't have enough good compost available. The other main benefit is that we can actually inoculate the leaves of our plants, something we can't do with compost.

There has been some good research on compost tea over the past 10-15 years, mostly on a larger scale. Vineyards have achieved good control of mildews and even been able to harvest their grapes *several weeks* early, giving them a head start on wine making. Food growers have controlled diseases and documented many other benefits for plant health. Golf courses and parks have reduced pesticide, chemical fertilizer, and water use, substantially lowering costs while creating healthier turf. Even Harvard University is using compost tea. I've had great success with compost tea in my own gardens and the gardens of clients. I've controlled diseases such as mildew and insects such as spider mites.

Making Compost Tea

To make a good tea, you need to get a lot of factors right - air pressure, water quantity, size of the air bubbles, amount and types of compost and microbes foods, and on and on. That means you either need to purchase a quality brewer that has been thoroughly tested and has the data to support that, or

build your own and test and tweak it until you get it right. The first option may cost you at least a couple hundred dollars for a 5 gallon brewer, but that's actually cheaper than the testing that needs to be done to properly build your own. I use an excellent brewer made by Keep It Simple, and there are other great brewers out there, too.

There's plenty of advice out there about how to build your own brewer for as little as $25. This can be a lot of fun and you might make a decent tea, but it generally works out that most homemade brewers don't make a good tea until they've been tested and tweaked. There are just too many variables. You probably won't do any harm, though, if you use good compost and if the resulting tea smells good, so it's a great way to start experimenting. If you use a cheap aquarium pump, I recommend using only 1 gallon of water in the bucket in order to ensure you have sufficient oxygen.

Whether you buy a brewer or make your own, here's how it works. You start with a small amount of exceptionally good, aerobic, fully finished compost. A mixture of two or three different composts is even better. You can put this compost first into a mesh bag or directly into a bucket of clean, room temperature water. By clean, I mean it can't have chlorine in it. If you use city water, you need to let that bucket of water sit out for 24 hours for the chlorine to dissipate, or you can turn your air pump on for 20 minutes instead and that does the trick. If your city uses chloramine, you need to tie that up by using ascorbic acid (vitamin C) or humic acids in the water. I use no more than 13mL of my particular brand of humate in a 5 gallon brew.

Your pump will blow air through tubes that are in the bottom of the bucket, the tubes attached with waterproof tape or weighed down somehow. The air goes through the water and compost, keeping the environment aerobic to favor the aero-

bic microbes, and physically pulling them off the compost. Examples of good microbe foods include molasses, kelp, fish, humic acids and rock dust. Obviously, these products should not have preservatives in them, because preservatives are designed to kill microbes. Molasses, other sugars, fruit juice and kelp promote more bacteria growth. Fish, seed meals, humic acids, yucca and rock dust promote more fungal growth.

Here's a recipe I have adapted and evolved for a 5-gallon homemade brewer. This takes 1-5 days to make. We don't really know when it's done if we're not testing, but 2-3 days is a good time frame. The mix is: 4-8 cups compost, 30mL unsulfured blackstrap molasses, 30mL liquid kelp, and 15mL liquid fish. You may be able to buy excellent compost from the brewer manufacturer, and a mixture of the microbe foods.

As I said, this generally doesn't produce a tea that gives much protection from disease or a big boost in nutrition, unless you get into using a better air pump and doing some testing to make sure you get all of the variables right. The main ingredient variables are water quality and temperature, compost quality and microbe diversity, and the mix of extra microbe foods you use. The main brewer variables are the oxygen level that is maintained in the water, the speed, size and placement of the bubbles, and the buildup of anaerobic pockets. Then there's the question of how long the brewer should run.

It's of critical importance to clean the brewer and all of the tubing from the air bubbler very thoroughly right after a brew is done. You don't want any biofilms left over, as they promote anaerobic conditions.

Using Compost Tea

Compost tea needs to be used as soon as possible after you

make it, because not long after that pump goes off, the oxygen in the water drops rapidly. Use it in the morning or the evening because many of the microbes don't like UV rays. My method of applying it is to strain it through nylon or cheesecloth into a quality backpack sprayer, such as those made by Solo. This allows me to spray a mist at 60 psi and thoroughly coat both sides of the leaves of all of my plants. A hose-end sprayer would work, but that water coming through the hose often has chlorine in it and it's very cold. I add EM and biostimulants in with the tea, even if I already added a small amount to the brew. Home gardeners might spray anywhere from once a month to once or twice a year.

A spray is best because research by Elaine Ingham tells us we want our leaves at least 60%-70% covered by microbes in order to prevent and even cure some disease. For foliar applications, which is the main method of application you'll do, you'll generally spray compost tea undiluted at 500mL per 1000 square feet, which means a good quality 5 gallon brew can do about an acre. It doesn't hurt to do more than that, though. You could spray your 5 gallons on a few thousand square feet and that's just fine. Of course, if you have tall trees, you'll need more.

The rule is 500mL per 1000 square feet for each 6 feet of height you have worth of plants. If your trees are 12 feet tall, you need 1000mL. We don't dilute the foliar sprays because we want the maximum number of microbes on the leaf surface as possible. It can also be a applied to the soil at 500-2000mL per 1000 square feet. This can actually be diluted with water in order to provide sufficient coverage. When planting, you can drench each new seedling with 500-1000mL of tea. Hydroponic systems use compost tea at 1 gallon per 40 gallons of water. It's applied to ponds at as little as 3 teaspoons of compost tea for a pond the size of a king size bed and 4 feet deep.

Chapter 16
Effective Microorganisms

EM is a liquid culture of specific facultative anaerobic microbes that provide amazing benefits when combined together in specific proportions. You can buy it from a manufacturer with the equipment and knowledge to put them together in exactly the right proportions and under the right environmental conditions. The 3 groups are lactic acid bacteria, yeast and photosynthetic bacteria, plus some other wild microbes that will be let into the brew.

They provide for each other to contribute a host of benefits to our gardens. They create an abundance of antioxidants and controlled breakdown of organic matter. Really, I think of them as providing all of the same benefits as the other beneficial microbes I hope to house in my garden, but they just happen to be exceptionally good at it when they get together.

After its value was seen in soil and composting, EM started to be used in other areas with astounding results. It has helped plants beat diseases such as *Botrytis*, insects such as weevils and other stressors. It also helps crops achieve higher brix and longer storage. One study sticks in my mind because a 50% increase in yield was obtained just with EM. It's also been found to have uses with animals. Initially with livestock, they found it helps to control odors, diseases and insects when sprayed in the air and on the animals in barns. It also acts as a probiotic for animals as part of their water and feed.

It cleans polluted water and can actually make dirty water drinkable. It has been used to clean up part of the ocean in a bay in Japan. It is also used to clean septic systems and sewers, where it reduces odors, toxic gases, sludge, pathogens, nitrates and phosphates and ties up heavy metals.

Of course, it wasn't long before humans tried drinking it. In my opinion, it's probably one of the best probiotics in the world. Now of course, EM is not a magic bullet and results vary depending on many environmental factors, but I have found it can work some miracles, sometimes very quickly and sometimes only when used consistently over a number of months.

Making Activated EM (AEM)

You can buy an existing mother culture from a supplier and multiply that, much like you would make yogurt. The process is called "activating." Unlike yogurt, which you can keep going forever, EM can only reliably be activated once, maybe twice, and then you need to get a new mother culture. You can definitely do it once, making 20 liters of good AEM from a 1 liter mother culture. This is done both to save money and to wake up the microbes that may be dormant if the mother culture has been around for awhile. The following measurements are per liter of water, but you can multiply and use bigger containers such as 4 liter or 5 gallon.

<u>Ingredients (per 1L)</u>
1-1.5 parts EM (40-60mL)
1 part unsulfured blackstrap molasses (40mL)
20 parts water, not distilled or reverse osmosis (800mL)
Clean, airtight bottle (1L), generally plastic with screw-on lid
pH paper to determine if your batch is good

<u>Directions</u>
1. Heat the water to 115-125F, and pour approximately half into your container to dissolve the molasses.
2. Add the EM, adding the remaining water last and stirring and/or shaking very well. There should be an airspace equivalent to about 10% of the bottle on top.
3. Some people like to leave the lid off for the first 24 hours to

encourage some air. Then tighten the lid and keep the bottle warm for at least 2 weeks, preferably longer. Between 95F and 110F is the optimal temperature. Even keeping it warm for just the first few days is helpful.
4. After the first few days, the container needs to be burped every day or two simply by opening and closing the lid.
5. The pH will drop as it ferments. It can be used as soon as the pH is below 3.9, but preferably below 3.7. It should also have a sweet smell. It's better left to ferment for at least 4 weeks for highest benefits.

EM mother culture stores for 6-24 months, or potentially a few years, whereas activated EM usually only stores for 1-6 months. Still, a really good AEM batch can potentially store for 2 or more years. After fermentation is complete, cooler room temperatures between 50 and 70F will keep it longer. Store it out of direct sunlight with the lid tight. Indirect sunlight is beneficial.

Using EM

EM is preferably applied in smaller doses, more often. Like compost tea, it could be daily, weekly, monthly, or seasonally. Application rates are the same for EM and AEM, the most common suggested rate for agriculture being approximately 90 to 900mL per 1000 square feet per year, spread out over as many applications as are feasible. The application rate given for gardens is 1 gallon per 1000 square feet per year. I go for the high end of the agriculture rate at 900mL per 1000 square feet per year. More importantly, I generally spread this out into 1/3 cup (80mL) per 1000 square feet per month from early spring through late fall. I may not get to the 900mL, but it's more important to me not to use too much EM and to achieve a sufficient dilution. If you only want to spray 3 times each year, I still recommend you go for this 1/3 cup.

I usually end up diluting it 1:200 with water, or at a bare minimum 1:100, which would be 5-10mL of EM per liter of water. It's technically supposed to be 1:500 or even 1:1000, but that's a lot of water and pretty much impossible with a backpack sprayer. Despite the cold water not being the greatest for the microbes, a hose end sprayer works really well for this because you can just set the ratio on the dial and spray until your EM is gone.

Once your EM or AEM has been diluted in water - often referred to as "extending" the EM - and mixed with any optional biostimulants, it should be used within a few hours. It's generally recommended to mix it again with equal parts unsulfured molasses, even though this was also done during the activation stage. EM can also be sprayed on compost, ponds, and buildings, and even on pets and livestock. It's entirely safe for people and animals to enter the areas after spraying.

You can see that EM provides many of the same benefits as compost tea, but it's different. It's a mixture of only a handful of species of mostly facultative anaerobic microbes. The shelf life is quite long and the quality of the product from the manufacturer is fairly consistent. With compost tea, on the other hand, we're going for maximum diversity, with as many different species of aerobic and facultative anaerobic microbes as possible. The shelf life is very short and the finished product more variable. Incidentally, I always put some EM in my compost tea when I'm brewing, at 30mL per 5 gallons. This is not only to make sure those microbes are there, but more to hopefully fill up any anaerobic pockets with these facultative anaerobes that can live there.

I generally recommend EM over compost tea as a starting point for most gardeners because it's much less expensive and easier to get started. I use both and the serious gardener may eventually want to, as well.

Chapter 17
Supplementing Nutrients (Step 5)

Microbes and plants need nutrients. We can supply most of these nutrients through good mulches and well-made compost, but not only do we need the nutrients, we need them in specific amounts in relation to each other. That's were a small amount of specific fertilizers come in, to move towards these ratios. When I refer to an organic fertilizer, what I mean is a fertilizer that would be allowed on an organic farm or garden.

Applying more is not always better. The application of N-P-K fertilizers and dolomite lime "for good measure" will cause problems more often than not. In the long run, you'll get higher yields by applying less fertilizer. You just need to apply the right fertilizers.

Mineral Fertilizers

Naturally-mined mineral products such as calcitic lime and glacial rock dust can be incredibly beneficial for the garden. Other than rock dust, most mineral products are composed primarily of just one or two minerals, such as calcium and phosphorus. Generally, they should not be applied in much quantity without both a soil test and often visual verification of certain conditions in the garden.

Fertilizers Derived From Plants And Animals

Many of the natural products organic gardeners used in the past are now unavailable to us because of their environmental consequences. For example, here are the meals we probably shouldn't use anymore: blood meal, bone meal, alfalfa meal,

canola meal, corn gluten meal, cotton meal and soy meal, just to name the main ones. Blood and bone meal bring the risk of spreading mad cow disease. Plant meals are mostly genetically modified now. Kelp, molasses and humic acids are still good organic fertilizers. Sea minerals and fish fertilizers are others that come from the ocean. We'll look at all of these in the biostimulants chapter.

Blended Fertilizers

In garden centres, you can find blended fertilizers, and you can find recipes online for how to blend together your own. Either way, these will usually include many of the following ingredients: calcitic lime, dolomite lime, gypsum, rock phosphate, bone meal, guano, greensand, kelp meal, fish meal, and seed meals such as soy meal.

But we don't know if our garden needs all of these things without a soil test. It may very well be that we are pushing the nutrient ratios further apart by adding all of this. We can certainly take the rock dust and kelp meal and apply them without a soil test as well as other biostimulants, but for the mineral fertilizers, we should use them only when we know we need them.

Dry Versus Liquid Fertilizers

Many of our fertilizers are dry, such as crushed or ground-up rock. Examples are rock dust, calcitic lime and rock phosphate. They're applied in the garden with a spreader or even by hand, or best of all, mixed thoroughly into the compost pile first. Along with organic matter and microbes, these dry fertilizers are often the basis of a soil management program. A fine ground product is better than a coarse grind because it is more quickly available.

Liquid fertilizers can help a plant deal with stress, give it some energy, and move it from vegetative growth to fruiting. They're often broad-spectrum biostimulants such as liquid fish, kelp and sea minerals. More recently, liquids that provide just one mineral are being used more and more to correct specific soil nutrient deficiencies. Liquid calcium is the main one that comes to mind. You may have enough calcium on a base saturation test, for example, but a liquid calcium will often help make it available. Liquids can be applied through an inexpensive hose-end sprayer, or backpack or pump sprayer. The idea is to create a mist that thoroughly coats both sides of all leaves.

Where To Find Fertilizers

Some fertilizers can be difficult to find. You won't find all of the ones I recommend at your local garden centre. You'll do a little better if you go to a farm supply store or a store that supplies the landscaping industry. I've lived in places where I could go into a wholesaler and get decent prices. You may also need to take your search online. Many of the liquid products are economical to buy online and ship, but this isn't the case with the mineral fertilizers. For them, you can still use the Internet to locate a local source.

How To Apply Fertilizers

The best time to apply the soil-building mineral fertilizers is in spring or fall. I prefer to split my applications up into 4 times per year. For example, instead of applying 40 pounds of calcitic lime all at once in the fall, I'll apply 10 pounds in early spring, mid-spring, summer and fall. Other fertilizers are applied regularly throughout the year, especially liquid fertilizers and biostimulants that keep a crop growing. When it comes to determining how much to apply, the soil lab will tell you that.

Chapter 18
Calcium And Phosphorus

Calcium

Calcium is the most important mineral to get right first. We're looking for 60-75% calcium on a base saturation test, and a 10:1 calcium to magnesium ratio with a minimum of 2000 pounds per acre of available calcium on a Reams test. This goes down to 60% and 7:1 for grasses/grains and very sandy soil. If your calcium is less than 60% on a base saturation test or 7:1 calcium to magnesium on a Reams test, there's a good chance your soil will be compacted and riddled with grassy weeds, your soil food web will be unhealthy, your plants will be sick, and your fruit will be weak and easily bruised.

Liquid Calcium And Micronized Calcium

There are many forms of liquid calcium, but the most common is generally from liquefied calcium nitrate, which is 9-0-0 with 11% calcium. It's not technically considered organic, but it's one of the rare synthetic products that's worth using. There are organic versions available, too, such as one from calcium lignosulfonate and others from micronized calcium carbonate. These are applied in very small doses because they're so readily available to be used by microbes and plants, and can be spread out so that not much is needed. Often, from 1/3-2/3 cup per 1000 square feet is all that's used, or even less.

Calcitic Lime - 30% Calcium, 4% Magnesium (Varies)

Calcitic lime is the main rock fertilizer used to increase calcium levels, especially when the base saturation test is low. Some soil labs may recommend 45 pounds per 1000 square feet, while some soil scientists like Arden Andersen advocate

starting out by using less, such as 10 pounds, perhaps applied more often. In North America, calcitic lime should be between $7 and $20 for a 50 pound bag, so it's definitely not too expensive for a typical residential garden.

Dolomite Lime - 22% Calcium, 12% Magnesium (Varies)

Dolomite is approximately 22% calcium and 12% magnesium, a 1.8:1 calcium to magnesium ratio, whereas calcitic lime is approximately 30% calcium and 4% magnesium, a 7.5:1 ratio. Too much magnesium in the soil can cause nitrogen to volatize into the air and soil to compact. Dolomite generally brings in too much magnesium for what we need. If you had a soil with extremely low magnesium in relation to calcium, such as a 12:1 calcium to magnesium ratio, then it might make sense to use dolomite, but I never do.

Gypsum - 22% Calcium and 17% Sulfur

Gypsum is calcium sulfate. It's in the same price range as calcitic lime. I use it for the sulfur when I need it. And I use it very often as a calcium source along with calcitic lime and soft rock phosphate. It helps bring more oxygen into an anaerobic soil, so it's even used when calcium is adequate.

Phosphorus

Phosphorus is the other most important mineral. It's generally present in the soil, but is often unavailable in soils with a low organic matter content and a lacking soil food web. Having active biology in the soil is probably the most important factor in getting phosphorus into plants. Phosphorus is in every living cell. It's the major catalyst in all living systems, which means its presence is vital for many other reactions to take place in the plant, and for many other nutrients to get utilized.

A Reams test gives the best information on phosphorus availability, and for this, the ideal number would be 400 pounds per acre. For either test, the ratio of phosphate to potash would ideally be 2:1 in general, not 1:2 as many labs recommend. It should be more like 4:1 for grasses and leaf crops, such as lettuce and greens. When it gets lower than this, plants will suffer and be more prone to insect and disease damage, and there will be more broadleaf weeds such as plantain.

There are 2 important methods of maintaining phosphorus levels and availability in the soil. The first is that we need to learn to make high-quality compost that will supply phosphorus and microbes that make phosphorus available. The second is that we need to promote mycorrhizal fungi in our soil and bacteria that specialize in moving phosphorus.

Rock Phosphate - Mainly Phosphorus And Calcium

Hard rock phosphate and soft rock phosphate cost $20 to $40 for 50 pounds. They can be difficult to source, but some farm supply stores have them. Hard rock phosphate is the more commonly available of the two, containing approximately 30% phosphorus and 30% calcium. It's mostly tricalcium phosphate and is difficult for plants to get out of the soil because the phosphorus is bound tightly with the calcium. In my experience, it won't give as effective a result as soft rock phosphate.

Soft rock is now considered superior to the hard rock because it's colloidal, meaning it's in a form that won't leach and doesn't tie up as tightly as hard rock. Like hard rock, it may only be listed as 3% available, but over a few years, it's 100% available to plants. It's often recommended at 10-45 pounds per 1000 square feet. I like to spread this out into 4 applications throughout the year or add some of it to the compost. You can get a powder form and sometimes a granular form. The best products come from Idaho, North Carolina and Tennessee.

Chapter 19
Other Major Nutrients

Rock Dust

A good quality dust is one of the most important mineral soil amendments, containing an abundance of minerals that can be applied to the soil and used by microbes and plants. You may be able to find a good dust locally from a quarry for a very low cost, or you may have to buy it at a garden centre or other fertilizer supply store where it costs $20-$30 for 50 pounds.

Rock dusts have produced amazing results, such as doubling yield and vastly increasingly nutrition in vegetables. Vegetables grown with rock dust are bigger, tastier, and much more nutritious. Use between 150 and 500 pounds per 1000 square feet, although good results have been seen with much less.

Magnesium

Magnesium helps give structure to soil. That's why we need a little more of it on sandy soils as compared to clay soils, to help that sand glue together a little better. Too much magnesium in relation to calcium causes soil compaction, a common occurrence. Langbeinite is approximately 27% sulfur, 22% potassium and 11% magnesium. It 's also known as sul-po-mag or K-mag, and is a good, natural product that is useful if a soil test indicates you need sulfur, potassium and magnesium. It's a bit pricey at $30 to $40 for 50 pounds and I've never had occasion to use it. Another source of magnesium is epsom salts, also known as magnesium sulfate. It contains approximately 16% magnesium and 14% sulfur, and costs about $10 for a few pounds. It can be used as a foliar spray or on the ground, when you know you need magnesium and sulfur.

Potassium

Potassium is involved in many plant processes, but extra potassium is not needed in the soil of most home or market gardeners who are using compost and mulch. Traditionally, we go for 2-5% potassium on a base saturation test and a 2:1 phosphate to potash ratio on a Reams test, up to 4:1 for grasses and greens. Langbeinite supplies potassium and was mentioned in the magnesium section. If my soil had a potassium deficiency, I might also use some seaweed if I could get my hands on it, as well as granite dust and ash. Granite dust is 3-5% potassium, while wood ash can have a potassium content as high as 10%.

Greensand is a sandstone with approximately 7% potash and a fair amount of iron and silica, as well as a very broad spectrum of trace elements. Although the potassium is tightly held and slowly released, I like greensand because of the benefit of the silica and trace minerals that come with it, although it is a bit pricey at $25-$40 for 50 pounds.

Potassium sulfate is white salt. It's expensive, but you only need 2 pounds per 1000 square feet when potassium is low on a soil test. A 50 pound bag costs $40-$50, but you might be able to find 5 pounds for $15 or less. You want the organic version, not the chemical, and not potassium chloride.

Sulfur

Sulfur is important, and lacking in many soils, which is one reason why gypsum is often recommended along with calcitic lime. I don't tend to use elemental sulfur because it can create sulfuric acid, tie up calcium and cause your fruit to rot at maturity, but some people use it successfully. Langbeinite, potassium sulfate and epsom salts, all discussed above, contain

sulfur, too. We're looking for a 1:1 potash to sulfate ratio on a Reams test.

Sulfur bonds to excess cations and leaches them, provided there is sufficient calcium. It will bind with calcium, magnesium, potassium and sodium, and then water will leach some of it down. I use an appropriate form of sulfur when a soil test indicates I have too much of one of the cations. Using the right form of sulfur helps to kick the calcium, magnesium, potassium and sodium toward their appropriate numbers.

Nitrogen

Nitrogen is the basis for all amino acids and proteins in our bodies and the bodies of all living things. While rainfall and lightning bring some of this nitrogen down into the soil, nitrogen-fixing bacteria provide most of it. They take nitrogen out of the air and convert it into other forms of nitrogen that plants can use. Chemical nitrogen fertilizers are overused in conventional gardening, especially early in spring before the microbes are ready to use the nitrogen, but nitrogen is important in small doses.

Liquid fish is a good nitrogen source that we'll look at in the biostimulants chapter. It doesn't provide a huge amount of nitrogen, but it's good quality and definitely helps build proteins and amino acids. Manure should be composted first. It's great to get different sources, but rabbit, chicken and horse manure are the highest in nitrogen. Compost also supplies nitrogen. It's the manure, food scraps and fresh plant residue that contribute most of this to the pile. Applying 1/2 yard (1/6 inch) of compost per 1000 square feet each year will give you a lot of nitrogen as well as phosphorus and potassium, slowly released by microbes. You really need look no further than good compost for much of your nitrogen needs.

Chapter 20
Chemical Fertilizers

Some people may choose to use specific chemical fertilizers if their goal is optimal garden health. I don't mean the usual N-P-K fertilizers like 21-7-7 and 10-10-10 that I used to broadcast on the golf course. I'm referring to a different set of fertilizers. You don't need to use any of these chemicals to make healthy soil and I'm not going to try to convince you to do so. It's rare that I use them myself, and the majority of the products in this book are organic.

My ultimate goal is to grow the healthiest food and ornamental plants possible. I can certainly grow healthy plants with organic products, but in order to get optimally healthy plants, a couple of chemical fertilizers can be helpful. There is a philosophy one step away from the organic movement that some people call "biological", and like organics, the goal of this movement is to grow the healthiest food possible while improving the health of the environment.

It turns out there are certain chemical fertilizers that can help us grow food that has even more nutrition than organic food. These aren't the chemicals used by conventional farming and gardening today, but they're still chemicals that can hurt soil life if used improperly. When used consciously, however, in very small amounts based on soils tests, they can be very helpful in getting more nutrition out of a crop.

These fertilizers are used primarily to provide energy to a crop and soil that organic products can't provide. In your garden, for example, you might apply a couple of pounds of 11-52-0 to give the push a crop needs to go from say, 8 to 12 brix. I've listed several of the main ones below, but you may get a couple of others recommended on a soil test, particularly nitrogen

sources such as ammonium nitrate 34-0-0, or 28%/32% urea-ammonium nitrate, or even potassium nitrate when you're low in potassium.

Calcium Nitrate - 15-0-0 with 19% Calcium

Calcium nitrate is quite useful when applied at only a few pounds per 1000 square feet. It's even used at as little as a half pound per 1000 square feet to make nitrogen more available. The liquid calcium version that I mentioned in the calcium chapter does this, too. I've seen 20 pounds for $20-$30.

Monoammonium Phosphate (MAP) - 11-52-0

MAP contains a lot of phosphate and a fair amount of ammonium, too. I've used this one in regions where I couldn't find any soft rock phosphate, or to "loosen" existing phosphate, when I seemed to have plenty on a conventional soil test. Diammonium phosphate (DAP) isn't recommended. I would only use MAP if nitrogen and phosphorus are both low, at 1 to 4 pounds per 1000 square feet, combined with molasses, while focusing on soft rock phosphate in the long term. I've purchased 50 pounds for less than $30. Of all the chemicals, this is probably the first one I would recommend if you can't find soft rock phosphate.

Phosphoric Acid - 75-85% Phosphoric Acid

Food grade 75-85% phosphoric acid is useful in a foliar program. Spraying 2-4 teaspoons with some fish and kelp and 2 quarts of water per 1000 square feet every couple of weeks during the growing season can be very helpful in keeping the phosphorus, and therefore the brix, at appropriate levels. It should cost less than $20 for a liter. It's corrosive, so be extremely careful with it.

Ammonium Sulfate 21-0-0 + 24% Sulfur

In the long term, the focus should be on compost and cover crops for nitrogen, but this product can be helpful during the transition. The best kind to use is the dark-gray-colored form, a by-product of the nylon industry. This product is one of the best for raising energy mid-season when you want to promote fruiting in the plant. The cost is $0.20-$3 per pound. The rate is 2-4 pounds per 1000 square feet on the lawn and in the garden. I use only 2 pounds.

Growth Versus Fruiting

For the first 5 or 6 weeks after plant emergence, you can focus more on “sweet” fertilizers that provide more quickly available calcium, such as organic liquid calcium, or synthetic calcium nitrate. After that, or whenever you see buds, you can focus on “sour” fertilizers to promote fruiting, such as soft rock phosphate, or synthetic 11-52-0 and ammonium sulfate. I actually apply a simple recipe to promote fruiting that I learned from Dan Skow: 4 Tbsp of apple cider vinegar and 2 Tbsp of ammonia in 2 liters of water per 1000 square feet. Ammonia can be difficult to find anymore, but I found some at a hardware store.

Boron helps fruiting, too. If I have it, I might instead spray 3 Tbsp liquid calcium mixed with 2-4 tsp boron, along with 100mL liquid fish hydrolysate, 20mL kelp and 1 to 2 Tbsp of apple cider vinegar, in 5 liters of water per 1000 square feet. You’ll probably want to do them several more times through the remainder of the season in order to keep up that fruiting energy.

Chapter 21
Biostimulants/Micronutrients (Step 6)

There are more than 80 elements, many of which are important in small amounts as catalysts and enzymes in the soil and plants. These are called trace minerals or micronutrients, and examples are iron, manganese, copper, molybdenum and selenium. Our food supply is tremendously lacking in most of these, and our health is suffering as a result. Biostimulants can increase photosynthesis and respiration in plants, increase yields, and increase brix and nutrition in food, making it taste better and store longer.

Sea minerals (Ocean Water)

To me, this is the most important broad-spectrum micronutrient source available. It provides a broader range of micronutrients than any rock dusts I've seen and the crop response from sea minerals is often very impressive. If you live near the ocean, you can apply it at 1 cup per square foot of soil. Nowadays, there are also very concentrated liquid sea mineral products on the market. They contain over 80 natural source minerals and active organic substances from ocean water. Many gallons of seawater are processed to produce a single gallon. The price of the brand I use is about $60 for a gallon or $20-$25 for a liter if you can find it in that smaller size.

Kelp

Kelp contains over 70 minerals, vitamins, chelating agents and amino acids. Perhaps more importantly, it's an excellent source of cytokinins and auxins, both natural plant growth hormones. This is one of the least expensive, yet most highly

beneficial products out there. In the soil, the benefit of using kelp meal and fresh kelp from the beach is that you get a huge amount of nutrients, ready to be used by plants and microbes. Using kelp meal as a micronutrient fertilizer, we apply 3-10 pounds per 1000 square feet. A 50 pound bag costs $50-$80, while you can find 10 pounds for $20-$30. Kelp from the beach can go on the soil as a mulch layer where it will disappear quickly, or can go into the compost.

Liquid kelp has the same nutrients, but we use it for its natural plant growth hormones, those cytokinins and auxins that stimulate many processes in plants. It's used as a foliar spray, where we apply perhaps only 20mL per 1000 square feet. It's $10-$25 for a liter, which is all most people need.

Liquid Fish Hydrolysate

An emulsion is a liquid generally made from the by-products of fish caught for food, such as the head, bone and guts. This mixture is cooked to kill putrefying bacteria. The resulting emulsion is often a lower quality product with a lower nutrient content than a hydrolysate, but is still beneficial to use. A hydrolysate is a liquid made with by-catch, which is all of the unwanted fish that were caught in the process of catching other more desirable fish. The whole fish is used in this process. Instead of cooking, it's digested with enzymes at cooler temperatures, ground up and liquefied. Many of the oils, amino acids, vitamins, hormones, and enzymes remain in the product. It's $20-$30 for a gallon of quality emulsion or hydrolysate. The application rates vary widely, from approximately 400mL per 1000 square feet for my hydrolysate to 3 liters per 1000 square feet for some of the emulsions I've seen.

Fish meals contain 5-12% nitrogen. The oils are removed to increase the nitrogen content and prevent spoiling. They're

applied to the soil or mixed in a foliar spray. It's $45-$70 for 50 pounds, which covers 500-1500 square feet. I mostly use sea minerals because of sustainability issues with using fish.

Unsulfured Molasses And Other Sugars

Molasses provides some nutrients, but is mostly just a great source of carbohydrates, which are food for microbes. It's a very good idea to apply it with the microorganism products because it gives them instant food to begin working with. The unsulfured variety is preferred because the form of sulfur used in most molasses is there to kill microbes. A mixture of 2/3 cup molasses and 2/3 cup liquid calcium mixed is 2 quarts of water per 1000 square feet is often sprayed on the soil right after planting to suppress weed germination. Sometimes it's just the simple things that our garden needs. Microbes need sugar. Some kind of sugar source should be used in nearly every foliar spray. It's often molasses, but other sugars can be used instead.

Humates

Humic and fulvic acids are present in compost and humus. It's extremely beneficial to build them up in our soil. It can also be useful to buy them as a product that is derived from leonardite, a soft brown coal, or other kinds of shale or humate deposits. I use humates mostly in liquid foliar applications. The main benefit here is that the plant will be able to take up and utilize the other nutrients in the solution many times more effectively because of how the humic acids combine with the nutrients, a process called chelation. The dry product I used to sell was used at 2-4mL per 1000 square feet, definitely no more, and the cost was low at $15 for a pound.

These other biostimulants are discussed in the full book: soil conditioner, yucca, hydrogen peroxide, enzymes and vitamins.

Specific Micronutrients

Most home gardeners needn't get into these and should instead focus on the other aspects of this book. Some of the micronutrient fertilizers are synthetic, but you can find many organic sources, too. The chelated forms are the best quality and most biologically available. The sulfate forms are second best, but the oxide forms are not as good.

How To Apply

Most of the products in this chapter are combined in water and sprayed onto plants. The water should be as clean as possible, and ideally not too cold. This spraying is preferably done in the morning or evening. I use a backpack sprayer for this, although a hose-end sprayer or irrigation system works, too. I generally use a base mixture of 80mL of EM or another microbial product, either 150-350mL of sea minerals or 300mL of liquid fish hydrolysate, with 20mL of liquid kelp and 80mL of molasses all together in 15 liters of water. This covers 1000 square feet. Check the label for amounts for your products.

Optionally, you can include any or all of the following: 500mL compost tea or more, 2-4mL humic acids, 1/2 tsp soil conditioner, 20-80mL yucca extract, 1/2-1mg of vitamin B12 or even a full vitamin B complex, 2/3 cup liquid calcium and any specific micronutrients you're using. A powder form of mycorrhizal fungi that goes through a sprayer can also be used in this mixture if you're doing a soil drench, but there's no use in applying it to leaves.

Chapter 22
Energy (Step 7)

In the soil, energy comes from microbes and animals, water, air, plant roots, and nutrients, and from the interactions of all of these things. It also comes from fertilizers. Soluble fertilizers have a big impact on this energy, especially nitrogen. Energy is one of the main reasons biological soil consultants recommend some chemical fertilizers. Putting a tiny amount of the right fertilizer on in the fall can result in a seemingly impossible increase in the availability of certain nutrients in the spring.

Organic gardeners need to learn to create energy in order to get higher brix, healthier crops and better yields. Chemical fertilizers are only one way of doing that. It can be done naturally, albeit a bit more slowly, with naturally-mined minerals and manure and compost and all of the things we've been over. Fish fertilizer can be very high in energy. There are some other ways, too, and that is what this chapter is all about.

Energy Released Per Gram Of Soil (ERGS)

Ergs is another Reams term. It's measured with an electrical conductivity meter, which gives the electrical current flow of soluble salts in the soil. Basically, it measures how much energy is available to plants and microbes. You want it to be between 200 and 800 microSiemens (µS) above the reading of a wild corner of your property that isn't gardened. If your ergs is too low, your plants won't grow very much. If it's too high, microbes and plants may suffer, roots may burn, and nematodes may infest. "Too high" is relative, as some people do well at 2000 µS, but mostly 800 µS and below is what we pursue.

Much of this energy-balancing is accomplished by reaching our other goals of balancing nutrient ratios, particularly calcium to magnesium and phosphate to potash, and building humus in the soil. In the short term, however, it can be difficult to get enough energy into the soil. Even 1-3 Tbsp of table salt per 1000 square feet can help, assuming you're low in sodium. Liquid calcium can help, as can using the soil conditioner product I mentioned in the last chapter, or tilling to dry out the soil, all of which increase energy. Too much rain/not enough air can also bring down ergs. We can use irrigation to do this on purpose if the ergs is too high. Lack of sodium, nitrogen and other nutrients can also bring down ergs.

Paramagnetism

Soil is paramagnetic. It isn't magnetic, but is mildly attracted by a magnet. Increased paramagnetism brings increased water retention, earthworm and microbial action in the soil. Plants experience better nutrient utilization, seed germination, resistance to predators, and resistance to environmental stresses.

Many soils are relatively low on the paramagnetism scale. In these soils, it will always be a struggle to raise healthy plants and nutrient-dense food. For most home gardeners it just makes sense to assume our soil could use a little more paramagnetism. Moving the calcium to magnesium ratio towards ideal will increase the paramagnetism, and soils with more organic matter and an abundant soil food web are often higher, too. The way to increase it even more, though, is by adding paramagnetic rock, generally from volcanic, granite or basalt sources. If you were thinking of adding rock dust anyway, you can get both the mineral benefits and energy benefits by using one that is paramagnetic. Most rock is paramagnetic, but you need one that is highly paramagnetic. There are many brands

on the market. Application rates are the same as for any rock dust, generally between 50 and 500 pounds per 1000 square feet.

Biodynamics

The goals of biodynamics are very similar to organic, with perhaps even more emphasis on working with nature and the sun, moon, planets and stars. The soil and soil food web are seen as the basis for plant health, but there is more emphasis on energy. Everything is energy. My first time putting a biodynamic practice to work was actually when I did my Permaculture Design Certificate. We made and applied a tree paste of manure, clay, sand and a biodynamic preparation that we then rubbed onto the trunk of some fruit trees. The goal was to strengthen the bark, control disease and even improve fertility.

The biodynamic preparations get a lot of attention. They require a bit of a leap of faith for most people before they'll try using them. They are a series of 9 remedies for the garden, used in homeopathic doses. For example, prep 500 is one of the main preparations. It's made by taking cow manure, packing it into a cow horn and burying it in the ground over winter. This is said to concentrate the earthly growth forces in the manure. It promotes roots, encourages lush growth, and aids germination, all most important in the early stages of plant growth. You can learn to make them, but for most gardeners, it may be better to buy them.

There are other non-biodynamic products called "energizers" which also often work with very dilute doses. Examples I've used successfully are Penergetic products to improve compost, water quality and plant health, and GSR Calcium to provide small, yet powerful doses of calcium into the garden.

Chapter 23
Amending Soil

The best time to amend your soil is *before* you plant a garden. With new ground, you can get compost, fertilizers, and microbial inoculants mixed right down into the root zone. You can do this in an existing vegetable garden in the off-season if the bed is empty. When you're planting a tree, you want to amend the soil over a larger area than just the planting hole. You don't want to remove the native soil from the planting hole and replace it with just lush topsoil and compost, because the roots may never want to leave that hole. It's much better to amend a bigger area with compost and minerals.

How To Improve Heavy Clay Or Sandy Soil

Gardeners often ask how to amend a heavy clay or sandy soil to improve water infiltration and drainage, air content and nutrient holding capacity. In many gardens, clay doesn't infiltrate and drain fast enough, while sand drains too fast. Clay may have a good cation exchange capacity, but not enough air and increased potential of compaction. Sandy soil may have plenty of air and resist compaction, but not hold onto nutrients.

The common advice is to add clay to the sandy soil, or add sand to the clay soil. My experience has been that both of these approaches are generally bad ideas. We definitely don't want to bring in a layer of topsoil and just spread it on top of the existing soil. Regardless of whether you're adding clay to sandier soil or sand to clayier soil, water movement will slow down or even stop until the top layer is nearly saturated, the opposite of what we want.

The logical solution is to till the two soils together, but it doesn't

always work. It can work well if the imported soil has a similar sand, silt and clay content to the existing soil, but if you till the sand into clay or vice versa, the sand often gets embedded in the clay and forms a soil environment that's like concrete. I've heard and read the recommendation to add sand to a clay soil many times, but in my view, it's bad advice. Besides, there's a much better way to improve clay and sandy soil, and that's organic matter in the form of compost, sheet mulch and cover crops. Work 2-3 inches of good compost into the top of a clay soil and it will improve infiltration and probably the amount of air and water available to your plants.

One product that can be useful in some gardens is zeolites, a type of clay. Unlike most clays, which are sheet-like and easily compacted, zeolites have a honeycomb structure that stays intact. Probably their biggest claims to fame in horticulture are their exceptionally high cation exchange capacity and their resistance to the shrinking, swelling and compaction that happens with many clays. They are an excellent addition to sandy soils that will receive a lot of foot traffic, such as golf course greens and soccer fields. Compost is great for this, too, and that's what I use, but zeolites don't break down compost.

Making Your Own Potting Mix

I'm not an expert on potting mixes, but I've had success by keeping it simple. Whether it be for starting seeds or containers, I use compost, good soil and sand. I mix the three, generally in approximately equal amounts, but with a little less sand than compost and soil. I use mycorrhizal fungi in both of these, along with some form of the liquid fertilizer mixture given at the end of the biostimulants chapter. So in fact, I guess I do end up using a lot of ingredients when the liquid fertilizer is included, but that's more of a bonus. The base is simply compost, soil and sand.

To Till Or Not To Till

Tilling can be done with a rototiller, pitch fork or other tools. You're turning the soil over so some of the lower soil comes up and some of the upper soil goes down. The main reason tilling can be useful is to get organic matter incorporated into the soil of a new garden bed or a fallow vegetable garden.

The other main reasons gardeners may till are: to make the soil look fluffy and nice, to allow more air and water into the soil, to reduce weeds, and to relieve compaction. Tilling can work in the short term for all of these, but not long term. The long term solution for all of these is balancing the nutrient ratios, increasing organic matter and improving the soil food web. The main disadvantage is the effect on beneficial microorganisms and earthworms, both of which are absolutely essential to the health of the soil. Tilling buries aerobic bacteria and slices beneficial fungi. Earthworms are also killed.

Other problems are potential imbalancing of nutrient ratios when compost is tilled in, and detrimental effects on soil structure. Organic matter is also oxidized faster than it is replenished. Annual deep garden tilling without adding more organic matter will cause a decrease in organic matter in the soil. This decreases soil fertility, nutrient-holding capacity and water-holding capacity, and hurts soil structure. Tilling has advantages and disadvantages. It can be successful in vegetable gardens long term if organic matter is brought in at the same time. No-till and sheet mulching can be successful over the long term, especially if the soil had some humus to start with.

A combination of the two may even be optimal. I may till in some compost in the beginning if my soil is very low in organic matter, and no-till and sheet mulch later on. I definitely opt for no-till long in the long term in order to establish a healthy soil food web. You can experiment to see what works for you.

Chapter 24
Lawns

Turf grasses are not all that different from the plants in your garden, but we do expect lawns to do more, and it's a bit more challenging to improve them. Use quality certified number 1 seed with a mixture of grasses appropriate for your climate and your soil. That means you probably shouldn't use sod.

Lawns that get a lot of foot traffic are better suited to sandier soil. If you're on clay, you'll want to bring up the organic matter content. Of course, if you're on sand, you'll want to use lots of compost, too, and perhaps zeolites. You'll definitely want to apply endomycorrhizal fungal inoculant, too. The nutrient ratios should be 7:1 calcium to magnesium rather than 10:1, and 4:1 phosphate to potash instead of 2:1.

Lawn Dethatching And Rolling

Dethatching - also called power raking - is done to rip out thatch, which is composed of the ligneous parts of the grass - rhizomes, stolons and crowns - not grass clippings, which are mostly water. Instead, we should be fixing the root cause of the problem, that we don't have the microbial diversity and numbers in our garden to break down this ligneous material. We especially need fungi. Fungi and other beneficial microorganisms need a healthy environment in which to live, just like grass plants and just like us. Thatch is exacerbated by cutting the grass too short and by applying too much nitrogen.

Light lawn rolling is often useful during the installation process to get a smooth surface, but that is pretty much the only time it's warranted. It compacts the soil, decreasing air space, water infiltration and water holding capacity.

Lawn Aeration

Aerating a lawn involves cutting small, round holes in the soil with a lawn core aerator and pulling the core out. Soil must be pulled out to get any benefits. The reason aeration is done is because it's thought to increase air and water penetration into the soil. While these are important goals and it works for awhile if enough cores are pulled from the soil, the effects are short-lived. The holes are often backfilled with sand, which may cause water problems, resulting in patches of dry grass and patches of overly wet grass. This happens when sand is mixed into soil that is a different texture.

Aeration shouldn't be necessary long term. For the most benefit, make sure the tines are sharp, the machine actually pulls cores out of the lawn, it's done in the fall or early spring (not summer), and if it's followed by top dressing with compost.

Lawn Top Dressing

Top dressing is often done with sand, which is not particularly helpful. What you should use is good quality, well-screened compost. Well-made compost brings many benefits to the lawn, including a broad range of nutrients, a huge number and diversity of beneficial microorganisms, reduced thatch due to the action of specific microorganisms, reduced disease, improved water-holding capacity, improved soil structure and reduced compaction.

You can also add other soil-enhancing products such as mycorrhizal fungi, rock dust and any minerals that you need, such as calcitic lime and soft rock phosphate. It's best to do all of this after aerating because the amendments and compost get down into the root zone where they belong.

Chapter 25
Non-Toxic "Pest" Control

The non-toxic pest control product industry is booming. We still focus on disease management instead of health management, and that means we'll always have pest problems. Pesticides don't give the plants the nutrients they need.

Pruning doesn't either. Diseased branches that still have green leaves are tremendously valuable to the plant. The plant may still be photosynthesizing with these leaves, and if it's a big branch or series of branches, pruning could mean a substantial reduction to the plant's photosynthesizing capacity. Conventional thinking is that we can remove the source of the disease if we take out the diseased branches, but this is ludicrous when you think about it because billions and billions of the disease-causing organism live all over our garden. We need to shift our thinking to realize that the disease isn't the problem. The problem is that our plant is unhealthy.

Insect Control

There are many insecticides available to organic gardeners, such as neem oil, pyrethrums, rotenone and sulfur products. These are by no means harmless. I'm not going to get into the above products, but I'll list two common remedies I have seen work.

Before that, I want to mention BTK, which is a product I generally don't recommend. *Bacillus thuringiensis* var. *kurstaki* is a microbial insecticide. It's a bacterium that is sprayed on plants and then ingested by insects, killing them. Like other pesticides, many insects are becoming resistant to it. Many beneficial insects are hurt or killed by it, as are some birds.

Large-scale applications of BT have substantially decreased the number and variety of moth and butterfly species, in turn affecting the birds and animals that feed on them. Here are the two insecticides I have used.

1. Horticultural oils have now mostly been refined into superior oils that can be used on many plants both as dormant oils and during the growing season because they're mostly saturated hydrocarbons and less dense. All of these oils are sprayed directly onto insects and plants, where they kill by membrane disruption and suffocation. When applied to plants, they also deter some insects from feeding and laying eggs.

2. Insecticidal soaps are also used on soft-bodied insects such as aphids, earwigs, mealybugs, psyllids, scale, spider mites and whiteflies. They work best when sprayed onto the insect where they interfere with the cell membranes. Rather than suffocating the insect like horticultural oils, they have kind of an opposite effect where they remove the protective waxes and cause the cell contents to leak out, which dehydrates and kills the insect. Soaps can also be sprayed onto plants that insects come in contact with.

Disease Control

There are many fungicides available to organic gardeners, such as chamomile tea, horsetail tea, copper and sulfur products. I'm not going to get into them, but here are 3 home remedies for fungi that I've seen work. Fungal diseases can't proliferate on a plant when the leaf surface pH is 8.4 or above. One of the reasons the first two remedies below may work is because they raise the surface pH. Copper products are used for bacteria and fungi. It has always been thought that there is something about the copper that is antimicrobial, but astute gardeners and farmers have suggested that the copper just

fixes a copper deficiency in the plants, giving it one of the main tools it needs to discourage pests.

1. Milk can help to prevent mildew, damping off, and other fungal diseases at 1/2 to 1.5 cups of milk per gallon of water, sprayed on the leaves. More than 4 cups per gallon of water caused other fungal problems. Any kind of milk works.

2. Baking soda works to prevent and eradicate powdery mildew, blackspot and a few others. A solution of 1-5 Tbsp of baking soda per gallon of water is generally recommended. Efficacy is greatly improved by adding an equal amount of-soap.

3. Garlic is a plant that contains sulfur. A spray can be made that prevents and eradicates certain insects, bacteria, and fungi. It is non-selective, so it will kill beneficial insects and microbes just as easily as it kills the bad guys. To make a solution, crush 2 bulbs of garlic and marinate it in 3 Tbsp of vegetable oil for 24 hours. Then add 2tsp molasses and mix well in 1 liter of water. Dilute this again with water at 50mL of mixture per liter of water and spray on the plant in the morning.

Weeds

In the short term, there are a few ways to get rid of weeds. We've seen how a thick mulch, cover crops and dense planting are some of the best methods of crowding out most weeds in a garden.

1. Corn gluten meal inhibits the germination of many common weeds. It's mostly used in early spring on the lawn, before the weed seedlings come up, and sometimes again in the fall. I've avoided it because most corn is genetically modified. That being said, if you can find a non-GMO corn gluten meal and

apply it at the right time in early spring, water it in and hope for about five dry days afterwards, it will inhibit germination of many of the common lawn weeds.

2. Your basic 5% acetic acid household vinegar kills many annual weeds with one application, and some perennials with a few applications. It's non-selective, so you can't go spraying it around the lawn, but it works well in patios and driveways. Mixing in 3% lemon juice makes it even more effective. You can purchase vinegar-lemon juice herbicides, but some of them have added chemical pesticides, so read the label. You can also purchase products with 20-30% acetic acid. You don't want to get that on your arms, but it's more effective than household vinegar.

3. This last one is the most interesting because it's more of a nutritional approach. Mixing 2/3 cup each of liquid calcium and molasses in 2 quarts of water per 1000 square feet and spraying it right after you seed can temporarily stop grass and broadleaf germination, allowing your plants to get ahead. The calcium stops the grasses and the molasses stimulates the phosphorous-releasing bacteria to bring the phosphate to potash ratio up towards 2:1, at least for a short time. This can work just as well as herbicides.

Long-Term Pest And Weed Management

The most important concept to remember is that weeds proliferate in unbalanced soils, and insects and diseases feed on unhealthy plants. A garden or field full of pests is not normal. Once you know that, it's all about implementing the steps in this book. When we stop spraying toxins, provide sufficient water, increase humus and improve the soil food web, balance soil nutrients and ensure there is proper energy in the system, pests go away.

Chapter 26
Garden Health Management Plan

Where do you start? Start with your own observations. Dig a hole. Check the texture, structure, color and smell, and look for earthworms and other insects. Measure the topsoil level and see if the roots are hitting a hardpan, and if they have fine root hairs that indicate enough oxygen. See if you have a good leaf and twig litter layer, and if your soil has some darkness that indicates organic matter. Compare this to the soil test value for organic matter. Do you need to add compost? It's difficult to get good crops sustainably without getting a good humus level. Microbial inoculants are always good.

If it's mid or late season and you have plants growing, look at them. Obviously, disease and insect damage indicate sick plants, but in addition to that, are the leaves a dark, vibrant color or do they have blotches, streaks or discoloration that indication one or several nutrient imbalances? If your fruit trees only produce fruit every other year, that's an energy or fertility problem. The same goes if your lettuce and other greens bolt to seed early or if your fruits and vegetable don't develop.

Soil tests are one tool for figuring out what kinds of problems you might need to address. Cation exchange capacity gives us an indication of the soil's capacity to hold cations. The CEC number should confirm the ribbon and/or sedimentation test you did. A low CEC means sandy soil with little organic matter. It will need to be watered and fertilized more often, but the good news is it's easier to balance the nutrients. Soils with a higher CEC need less irrigation and fertilizer, but are harder to balance because you need more fertilizer to make a change.

Look at your base saturation test and see if you have 60-75% calcium 7-20% magnesium, 2-5% potassium, and 0.5-3% so-

dium. If anything is low, you need to find materials from the fertilizer chapters that will contribute more of the lacking minerals.

The Reams test gives a better indication as to what was available in your soil right when the test was taken. Comparing it to the base saturation test, look for discrepancies. If any of the cations are plentiful on the base saturation test, but not on the Reams test, adding raw materials may not be as important as doing something to activate the nutrients you already have.

You're aiming for somewhere between a 7:1 and 10:1 calcium to magnesium ratio, with Reams test values of 2000-8000 pounds per acre of calcium. You're aiming for somewhere between a 2:1 and 4:1 phosphate to potash ratio, with Reams test values of 400 and 200 pounds per acre, respectively. You're aiming for a potash to sulfate ratio of 1:1. I tend to pay little attention to anion values from the more conventional part of a soil test, but I definitely look at them on a Reams test - particularly the phosphate mentioned above, as well as nitrate nitrogen and the cation ammonia nitrogen.

Liquid calcium often helps to activate calcium in the soil and can give you a huge jump on your Reams test. I'll often try this before investing in calcitic lime. Sugar and vitamin B12 can do this, too. Molasses often helps to activate phosphorus. All of these can be mixed together. Organic matter and microbes help to release everything. Simply adding some compost may bring potassium up on a Reams test. Gypsum supplies calcium and sulfur.

Health Management Program

There's no such thing as a recipe that works on all gardens. I've tried instead to give you the procedures to find the solu-

tions that will be best for your garden. That being said, I also want to give you some basic recipes so you can see where to start. All of the measurements given are per 1000 square feet.

Fall

If you're reading this in the summer, wait until fall to do these first tasks. If you're reading it in the winter, you can do these things in spring along with the "One Month Before Planting" section.

If your organic matter is low, add good compost that you've made or purchased. To build organic matter, I suggest at least 3 yards, which is about 1 inch over the whole area. If you don't have or don't want to pay for that much, that's okay. We've seen how less than 1/2 yard is plenty to bring in the biology and nutrients. If this is a vegetable garden, you may deeply till or double dig this into the soil the first year. Otherwise, you may lightly incorporate it into the top few inches of soil. On the lawn, rake it down into the grass. If you want, you can split this in half and apply half in spring and half in fall. You'll also want to maintain a mulch layer in the garden throughout the year. Leaves are generally the best choice for this, but straw or even a small amount of wood chips would be helpful, too. Sheet mulching is another good method of starting a new bed.

Send a soil sample into a good soil lab that offers Reams testing and hopefully base saturation testing, too. This test is important, so it's not optional. When you get the results back, do what they say to the best of your ability. A soil test is the best way for most of us to know which of the mineral products to use, as we don't want to go adding minerals without knowing we need them.

The main products you'll be looking for are liquid calcium, calcitic lime, gypsum, and hard rock phosphate or preferably soft rock phosphate. You may need other minerals, and you may consider calcium nitrate and 11-52-0. Then you'll look at molasses and other biostimulants to help unlock soil nutrients.

One Month Before Planting

If you didn't do the soil test and follow their recommendations, spread 5 pounds of calcitic lime with a broadcast spreader or by hand if that's all you have. After that, preferably in the morning or evening, spray a mixture of 80mL EM or another microbial product, either 150-350mL sea minerals or 300mL liquid fish hydrolysate, 20mL liquid kelp, 80mL molasses and 15 liters water. Spray this again every 1 to 4 weeks, along with other optional biostimulants.

Seeding And Planting

When preparing to seed vegetables, I soak the seeds overnight in a mixture of 5mL of kelp or sea minerals per liter of water. The next morning I take them out of the water and sprinkle with a small amount of mycorrhizal fungi powder. I spread them out to dry slightly for a few hours to make sowing the seed easier.

Spray the above foliar onto the soil after you seed plants, or directly onto the roots and foliage of transplants, sod, shrubs and trees as you plant them. Get mycorrhizal fungi onto the roots of all of these things while you plant them. For sod and seed, a powder can be purchased and sprayed. For transplants, shrubs and trees, it can even be rubbed directly on to the roots.

Happy Growing

I hope I've been able to give you some good strategies in these pages and I urge you to continue to learn more. This chapter provides a good summary and recommendations for a garden health management program. I like to boil it down into the following 7 goals. We need to:

- Stop using pesticides, harsh chemicals and GMOs.
- Provide sufficient water to the entire soil and mulch, some of it possibly coming from cisterns and/or ponds.
- Increase the organic matter and humus content of our soil with compost, mulch, sheet mulch, cover crops and humates.
- Increase the diversity and health of the soil food web with compost, mycorrhizal fungi, compost tea, EM and other inoculants.
- Remineralize the soil with rock dusts and balance certain nutrient ratios with calcitic lime, rock phosphate and other fertilizers, based on a soil test and garden observations.
- Use biostimulants to further stimulate the system, especially sea minerals, kelp and fish fertilizers, humic acids and molasses.
- Ensure the soil has enough energy by measuring and adjusting ergs, increasing paramagnetism and increasingly using biodynamics and other energizers.

Bibliography

Andersen, Arden B. *The Anatomy Of Life & Energy In Agriculture*. Metairie, LA: Acres U.S.A., 1989.

Andersen, Dr. Arden B. *Science In Agriculture*. Austin, TX: Acres U.S.A., 2000.

Astera, Michael and Agricola. *The Ideal Soil*. SoilMinerals.com, 2010.

Buhner, Stephen Harrod. *The Lost Language Of Plants*. White River Junction, VT: Chelsea Green Publishing, 2002.

Callahan, Philip S. *Paramagnetism, Rediscovering Nature's Secret Force Of Growth*. Austin, TX: Acres U.S.A., 1995.

Callahan, Philip S. *Tuning Into Nature*. Old Greenwich, CT: Devin-Adair, 1975.

Chaboussou, Francis. *Healthy Crops: A New Agricultural Revolution*. Jon Carpenter Publishing, 2005.

Cocannouer, Joseph A. *Weeds Guardians Of The Soil*. Old Greenwich, CT. Devin-Adair, 1950.

Fukuoka, Masanobu. *The One-Straw Revolution*. Emmaus, PA: Rodale Press, 1978.

Hamaker, John D., and Donald Weaver. *The Survival of Civilization*. California: Hamaker-Weaver Publishers, 1982.

Hemenway, Toby. *Gaia's Garden: A Guide To Home-Scale Permaculture*. White River Junction, VT: Chelsea Green Publishing Company, 2000.

Hermary, Heide. *Working With Nature*. Cowichan Station, B.C.: Gaia College Inc., 2007.

Howard, Sir Albert. *An Agricultural Testament*. London: Oxford University Press, 1943.

Ingham, Dr. Elaine. *The Compost Tea Brewing Manual, 5th Edition*. Corvallis, Oregon: Soil Foodweb Inc., 2005.

Jeavons, John. *How to Grow More Vegetables Than You Ever Thought Possible on Less Land Than You Can Imagine*. Ten Speed, 1991.

Kervran, C. Louis. *Biological Transmutations*. Magalia, CA: Happiness Press, 1988.

Kinsey, Neal and Charles Walters. *Hands-On Agronomy.* Metairie, LA: Acres U.S.A., 2006.

Krasil'nikov, N. A. *Soil Microorganisms And Higher Plants*. Moscow: Academy Of Sciences Of The USSR, 1958.

Lisle, Harvey. *The Enlivened Rock Powders*. Metairie, LA: Acres U.S.A., 2994.

Lovel, Hugh. *A Biodynamic Farm*. Austin, TX: Acres U.S.A., 2000.

Lowenfels, Jeff, and Wayne Lewis. *Teaming With Microbes*. Portland, Oregon: Timber Press, Inc., 2006.

Managing Cover Crops Profitably, 3rd Edition. Beltsville, MD: Sustainable Agriculture Network, 2007.

Martin, Deborah L., and Grace Gershuny, eds. *The Rodale Book Of Composting*. New York: Rodale Press, Inc., 1992.

McCaman, Jay. *Weeds: Why?* Sand Lake, Michigan: Jay McCaman, 1989.

Mollison, Bill. *Permaculture: A Designers' Manual*. Tagari, 1988.

Murray, Maynard. *Sea Energy Agriculture*. Austin, TX: Acres U.S.A.

Pfeiffer, Ehrenfried E. *Weeds And What They Tell*. Kimberton, PA: Bio-dyanmic Farming and Gardening Association, Inc., 1970.

Rateaver, Bargyla and Gylver Rateaver. *The Organic Method Primer: The Basics*. Sand Diego, California: Bargyla & Gylver Rateaver, 1994.

Shepherd, T.G. 2000: *Visual Soil Assessment. Volume 1. Field guide for cropping and pastoral grazing on flat to rolling country.* horizons.mw & Landcare Research, Palmerston North. 84p

Skow, Dan, and Charles Walters. *Mainline Farming For Century 21*. Austin, TX: Acres U.S.A., 1995.

Smith, Jeffrey M. *Seeds Of Deception*. Yes! Books, 2003.

Soil Biology Primer. N.p.: Soil and Water Conservation Society, 2000.

Tompkins, Peter, and Christopher Bird. *Secrets Of The Soil*. Anchorage, Alaska: Earthpulse Press, 2002.

Tompkins, Peter, and Christopher Bird. *The Secret Life Of Plants*. New York: Harper Perennial, 2002.

Walters, Charles. *Eco-Farm, An Acres U.S.A. Primer*. Austin, TX: Acres U.S.A., 2003.

Walters, Charles. *Fertility From The Ocean Deep*. Austin, TX: Acres U.S.A., 2005.

Walters, Charles. *Weeds Control Without Poisons*. Austin, TX: Acres U.S.A., 1999.

Wheeler, Philip A., and Ronald B. Ward. *The Non-Toxic Farming Handbook*. Austin, TX: Acres U.S.A., 1998.

Zimmer, Gary F. *The Biological Farmer: A Complete Guide to the Sustainable & Profitable Biological System of Farming*. Austin, TX: Acres U.S.A., 2000.