NYBG/125

NEW YORK BOTANICAL GARDEN

Grow More Vegetables Citywide

Bronx Green-Up's *Grow More Vegetables Certificate Series* is a free edible gardening course designed to teach the best organic techniques for growing vegetables safely and effectively, particularly in urban settings. This development of this online course material (outlines 1-5 and course handouts available online at http://www.nybg.org/green_up/tips.php) was made possible by The New York Community Trust.

<table>
<tr><td>Grow More Vegetables Certificate Series</td><td>3: Soils and Compost</td></tr>
<tr><td>Total Time:</td><td>2 hours</td></tr>
<tr><td>Learning Objectives</td><td>In this class, students will:
define what soil is and understand its properties
explore some simple ways we can evaluate our soil
learn the importance of organic matter and introduce other amendments to soil</td></tr>
<tr><td>Materials</td><td>Students should come to this class with a 1 cup soil sample from their gardens. Remind them in the previous class.
Samples of soil separates: sand, silt and clay
Sample of compost
Sample of garden soil without compost
Hand lens (10x is fine)
pH kits
Sample decomposers
Handouts: Soils in Organic Vegetable Gardening, Simple Ways to Evaluate Your Soil, Compost Made Easy, Soil Contaminants</td></tr>
<tr><td>Quiz
15-20 min</td><td>Review from last class: Seed-starting</td></tr>
<tr><td>Lecture
25 min</td><td>Soil is alive! Our plants can only be as healthy as the soil they are planted in. As a result, soil is the first thing to think about when growing plants in a garden. A basic knowledge of soil science, how to enrich soil and maintain its fertility are the foundations of good gardening practices.
Your goal in vegetable gardening is a well-drained, humus-rich soil because it can support a large amount of microorganisms and plant nutrients.
Humus is organic matter that has broken down fully, and is also called finished compost.
Earthworms are one simple sign of good soil—they do a great deal in building up the soil</td></tr>
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and providing aeration.

- Your soil should be loose, not compacted, so that roots can penetrate the soil easily, allowing a steady stream of nutrients to flow into the stem and leaves of the plant.

Ask students: What is soil?

- ½ pore space: where air and water move and can penetrate
- ½ solid: 90% is composed of tiny rock minerals from which soil was formed (these particles are referred to as sand, silt, and clay, and we can classify them by size)

How does soil form?

In the late 1800s, Russian soil scientists introduced the concept of soils being dynamic—that they developed over time to their current state, and also are constantly evolving and changing. They came up with the 5 soil-forming factors:

- **Time:** Soil development is a continuous process. Young soils tend to be thin, with few horizons or layers. Mature soils are deeper and more productive. How long the native bedrock has been subject to weathering influences the availability of minerals and humus formation.

- **Parent material:** Weathering is the breakdown of rock into smaller and smaller pieces. There are two types of weathering: **mechanical (physical)** weathering happens from physical factors like temperature changes and freeze/thaw cycle of water. **Chemical** weathering is the breakdown of rock due to chemical reactions. For example, limestone can dissolve in water, becoming a water-soluble nutrient that plants can uptake.

- **Topography** affects soil formation by changing water movement and soil temperature. Erosion on steep slopes often causes thin soils while low-lying areas often have deep, rich soils that drain slowly. *Example:* Nile River Valley

- **Climate:** temperature, moisture and seasonal distribution all affect soil formation. For example, more organic matter accumulates where decomposition is slow due to cooler temperatures.

- **Biotic factors:** plants, animals, and microorganisms also affect soil formation. For example, the type of vegetation affects soil development, such as leaf litter from pine forests increases soil acidity.

Ingredients of soil:

Here is a simple way to think about the makeup of soil:

Generally, half of soil is solid. Ninety percent of this solid half is composed of tiny rock minerals from which the soil was formed. These particles are called sand, silt, and clay, depending on their size. Most soils contain a mixture of the three. The other 5–10% is organic matter.

Pass around samples of these different ingredients for students to look at and feel. Front of room display can show how water moves through each sample.

- Sand – particle size is largest and therefore water drainage is greatest. Sandy soils drain the fastest, so water and nutrients often flow through (runoff) before the roots can absorb them.

- Silt – loose sediment with rock-dust particles usually 1/20 millimeter or less, has a fine, powdery texture; too much silt will have the same runoff problems as sand.

- Clay – particle size is smallest, drainage is a problem in soils heavy in clay; clay is slow to absorb water, but once it does it is very slow to dry out.

- Organic matter – living, dead and decomposing plant and animal matter. A soil organic matter content of 5-10% is ideal.

The other half of soil makeup consists of pores or air space between the particles, where air and water move and penetrate.

- Air – needed for plant roots and soil microorganisms to take up water. Half the volume of soil will ideally be pores, or air spaces. Plant roots cannot take advantage of available nutrients if they are suffocating.

- Water – contains dissolved minerals and providing the main source of nutrients for plants.

The image[1] below helps to show the relative particle sizes of clay, silt, and sand, respectively.

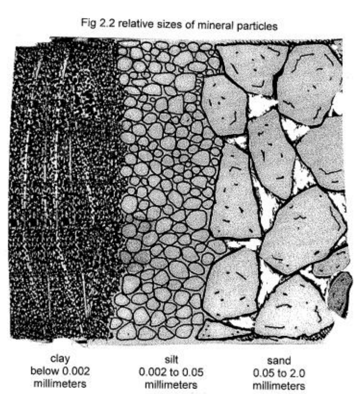

Image courtesy of NYC Compost Project

How to tell your soil's texture – Ribbon Test

Texture refers to the relative proportions of sand, silt and clay particles in a given soil.
Soil texture helps to us to know how well a soil can hold water and nutrients and provide room

Activity: Soil Texture Test 5 min	

for air circulation.

We will all do this together:

- Scoop up a handful of reasonably moist soil and squeeze it in your fist.
- Make a ribbon of soil between your fingers to gauge the texture.
- If you have a ball of soil sitting on your palm, try to squeeze it upward with your thumb to form a ribbon. If you have a ball of soil sitting on your palm, try to squeeze it upward with your thumb to form a ribbon.
- If your sample falls apart, you've got sand.
- If you can't make a ribbon, you have loamy sand.
- If you can make a ribbon, make it as long as you can and measure it.
- Light-textured sandy and silt loams form shorter ribbons than heavier silty clay and clay soils. Everything else can be classified as medium texture.

This chart can help you determine your soil's texture:

Soil textural group	*Soil textural class*	*Feel by hand texturing*
Coarse to very coarse	Sand, loamy sand	Gritty -- does not ribbon or leave a stained smear on hand.
Moderately coarse	Sandy loam	Gritty -- leaves smear on hand, does not ribbon -- breaks into small pieces.
Medium	Loam, silt loam, silt	Smooth and flour-like, does not ribbon, breaks into pieces about 1/2 inch long or less
Moderately fine	Sandy clay, sandy clay loam, clay loam, silty sandy clay loam, silty clay, clay	Forms ribbon; clays form longer ribbons than clay loams. Clay loam feels gritty.

Credit: University of Nebraska Lincoln Plant & Soil Sciences eLibrary
http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1130447039&topicorder=2&maxto=10

Optional: Show textural triangle
Soil Bulk Density Calculator (U.S. Texture Triangle)
http://www.pedosphere.com/resources/bulkdensity/triangle_us.cfm?345,312
This link will lead you to a calculator which determines the percentages of soil separates based on where your texture is located on the triangle.

Loam is soil composed of sand, silt, and clay in relatively even proportions (about 40-40-20% concentration respectively). This is considered ideal for gardening and agricultural purposes. Loams generally contain more nutrients and humus than sandy soils, have better infiltration and drainage than silty and clay soils, and are easier to till than clay soils.

Loams are gritty, moist, and retain water easily. In addition to the term *loam*, different names are given to soils with slightly different proportions of sand, silt, and clay: sandy loam, silty loam, clay loam, sandy clay loam, and silty clay loam.

Any extreme texture is undesirable.

- Clay soils hold water and nutrients well, but drain poorly and are difficult to work. When they dry out, they form large clumps.
- Sandy soils are generally easy to work and drain well, but are poor at holding water and nutrients.

Soil structure is the way soil ingredients hold together, the arrangement of soil particles.

- A soil with good physical structure will have pores and channels of many sizes, from the tiniest channel to large spaces that will allow rainfall to penetrate. Without adequate pore space, water cannot soak into the soil properly, running off and creating conditions of erosion (washing away the soil).
- Good soil structure allows for water to reach the root zone of plants, where it is most needed
- Even if the surface of the soil is dry, it may be moist below
- Soil organic matter (such as compost) helps to form and maintain the air passages and channels, protecting the soil from compaction.

Now, as we talk about the properties of soil, we'll be doing some simple tests that will help you evaluate soil in different spots of your garden.

How to tell if your soil has good structure – Fist Test
Does everyone have their soil samples? If not, pass out samples to use. We will all do the following with our own samples:

Activity: Soil Structure Test
5 min

Do the fist test. Squeeze a sample of reasonably moist soil in your hand. If you squeeze out water, the sample is too wet.

- If it falls apart easily, it does not have good structure. (*WHY? Too sandy*)
- If it holds the shape of your hand, even when you poke it gently, it does not have good structure. (*WHY? Too much clay*)
- If the soil breaks apart into small clumps when you poke it with your fingers, it has good soil structure.

Soil Compaction
When your soil is **compacted**, it lacks structure and does not get adequate aeration. These conditions kill microbiotic life, which is key to healthy, living soil.

- When soil is compacted, it becomes more difficult for plants to grow.
- Wet soils are heavy and easily compacted.
- Soil in your paths (between plantings) becomes compacted. This is one reason that raised beds are useful, since you often don't need to step inside a raised bed and compact the soil where plants are growing.

Soil erosion is loss of soil by way of wind or water. The loss of soil is a loss of nutrients that plants need to grow. If the productive layer of soil, called the humus or topsoil, is eroded away, then the garden can be very unproductive.

- Raised beds help to prevent soil erosion, as the walls help to hold in the soil.
- Planting cover crops (crops grown to protect and nourish the soil), applying compost or

	mulch are two steps you can take to prevent soil erosion. • Planting trees and shrubs can help prevent erosion. The roots of trees prevent excess water from washing away. In particular, planting native plants can help prevent erosion, since they are well adapted to local conditions. • Do not overwater, as you might wash away soil and nutrients in the process.
Activity: Site Evaluation 5 min	**Individual activity: A simple way to evaluate your garden site**[2] Sketch a simple map of your garden. The map will give you an idea of what soil characteristics you might find, and where improvements need to be made. This will help in the garden planning process. Your map should include: • Slopes and contours: Are these good places to plant? You may need to build supports, such as a retaining wall or terrace, on areas to prevent erosion • Waterways (including your water source: hydrant, spigot, etc.) • Wet areas (soggy places in early spring or after a period of rain) • Rocky outcrops: Will you plant here/improve the area first? • Spots where you see signs of: Eroded areas may need to be improved before planting • Existing trees and shrubs: How do they affect sunlight? Wind? • Buildings and other structures: how do the buildings/structures affect sunlight? Do they protect certain areas from high winds/storms? • Current vegetable plots: Is this the best place for the vegetable beds? *Each student makes a rough sketch. A sample sketch is available on p.14 of Start with the Soil (*by Grace Gershuny, Rodale Press, 1997).
5 min	**The Soil Community** *A good visual to share for this part of the lecture is the Soil Food Web. One great resource for that is the USDA's Natural Resources Conservation Service "Soil Biology Primer" found at:* http://soils.usda.gov/sqi/concepts/soil_biology/soil_food_web.html A great number and variety of creatures make up the soil community, from bacteria and fungi to earthworms and moles. These organisms grow, reproduce and die in soil. They contribute greatly to the health of plants. Each organism, plant or animal, has a role to play in the soil. **Producers** create carbohydrates (simple sugars) and proteins from simple soil elements, almost always by capturing energy through sunlight in photosynthesis. The plant uses this sugar, also called glucose, to make many things, such as wood, leaves, roots, and bark. Green plants and algae are our producers. **Consumers** are nearly everyone else: organisms, small and large that depend on the food created by green plants. Consumers feed on producers or other consumers; they cannot produce their

own food. Animals from simple protozoans to humans, yeasts and certain fungi are consumers.

Decomposers are the cleanup crew! Decomposers perform the function of breaking down larger organic materials, the dead plant producers and animal consumers, into smaller, simpler materials. Once this dead matter is broken down into its nutrient components, plants can absorb it and grow, bringing the nutrient cycle full circle. Decomposers are mainly bacteria or fungi that live in the soil. Microbial decomposers account for 60-80% of total soil nutrient cycling.

Another way to think about the soil community is as a natural system, like a forest or meadow. Year after year, the system thrives by recycling nutrients.

- Leaves fall and break down.
- Grasses and flowers grow, bloom and fade.
- Animals die and decompose.

All of this life adds organic matter to the soil. You want to try and mimic this cycle in your garden. Each time you harvest crops or pull weeds, you remove nutrients and organic matter from the soil. If you don't replace these ingredients, your soil will be depleted over time of the resources plants need to grow healthy. Organic matter can help replenish nutrients and improve soil structure, making work easier and a better environment for plants to thrive.

This being said, take a minute to think about the soil community in your own garden.
Make a list of some organisms, plants or animals you have seen contributing to the soil community. What is their contribution?

BREAK
Video clip from *Dirt! The Movie* (one option is: 46:00-53:00 turn off after Wes Jackson finishes speaking). Credit: Common Ground Media, 2009.

Video
7 min

Organic Matter
Pass around 1 container of soil and 1of compost, encouraging students to feel the texture of the samples and look with hands lens.

Discussion
15 min

<u>What it is</u>

- In the broadest sense, organic matter is made up of all living organisms and the remains of organisms that were once alive, which includes plants, animals and microorganisms.
- The end product of decomposition is **humus**—dark brown or black organic matter that is highly resistant to further decomposition. This is also known as finished compost.
- Not all soil organic matter is created equal. Fruit and vegetable wastes are easily degraded because they contain mostly simple carbon-based compounds. In contrast, leaves, stems, nutshells, bark and trees decompose more slowly because they contain stronger, more complex carbon compounds, like cellulose, hemicellulose and lignin. The ease and amount of time with which compounds degrade is determined by the complexity of the carbon compounds and generally follows the order: carbohydrates > hemicellulose > cellulose = chitin > lignin.
- Organic matter contains a host of microorganisms, like bacteria, enzymes and fungi. These organisms aid in the process of decay or breakdown of organic matter.
- The decomposition of organic matter is the key to unlocking nutrients and making them

available to plants.

- Most soil organic matter is present near the soil surface and root zone of plants (the rhizosphere), rather than deeper in the soil.

What it does

Compost Made Easy, a handout from NYC Compost Project, could be given out here. (Available at: http://www.nyc.gov/html/nycwasteless/downloads/pdf/materials/tipsheet-easy-compost-abono-facil.pdf)

- Stabilizes and holds soil particles together as aggregates(clumps), binding together sand particles and breaking apart large clumps of clay.
- Aerates the soil by creating pore space between soil aggregates
- Makes soil more friable (breaks apart easily) and easier to work so that plant roots can penetrate the soil profile adequately
- Helps soil to resist compaction and reduce erosion and runoff
- Reduces availability of metal contaminants in soil; organic particles will bind with metals and help prevent them from being absorbed by your plants
- Holds moisture and improves drainage, aiding the growth of crops by improving the soil's ability to store and transmit air and water, as measured by improved porosity, water holding capacity, and drought resistance
- Stores and releases plant nutrients safely and gradually throughout the growing season (macro- and micro-nutrients; increases cation exchange capacity)
- Feeds the microbiotic life of soil: worms, beneficial fungi, etc. (Provides a source of carbon and energy for soil microbes which cycle nutrients and fight plant diseases)
- Reduces wastes: composting (managing the decomposition of organic matter) recycles nutrients, making use of materials that might otherwise end up in the landfill, such as leaves and food scraps.

Common sources of organic matter

- **Compost** is made up of decomposed plant and animal materials (may contain small amounts of soil). It helps to improve soil structure and water-holding capacity, and adds nutrients, though in lower levels than manure. Compost is made from managing the natural decomposition process of organic matter.
- **Animal manure**: apply well-rotted or composted manure in the fall and work into the soil. Fresh manure can damage plants and may contain harmful pathogens or weed seeds. Do not use pet waste.
- **Cover crops,** like winter rye, alfalfa, hairy vetch and others, are grown to protect and nourish the soil. They are often planted after primary crops are harvested, and are later turned into the soil to decompose, adding nitrogen and organic matter to the soil. Planting a cold-hardy cover crop in the fall also helps hold additional snow during the winter (holds in moisture), insulates perennials and prevents soil erosion from winter winds.

How much should I use?

- A general rule: Use a 1-2 inch layer of finished compost in the spring before seeding or transplanting, and again in fall when putting your garden to bed for the season.
- If you are starting a new garden, incorporate a 3- to 4-inch layer of compost into the top

Lecture
10 min

6 inches of soil.

- In potting mixes, use 20-25% compost in the total volume of the potting mix.

<u>How may I evaluate the content of organic matter in my soil?</u>

- Visually evaluate: Darker brown means a higher humus content.
- Look for white threads of fungal mycelia and bits of un-decomposed organic matter.
- If your soil is biologically active, you will not recognize most crop residues from the previous season; soil organisms have worked to decompose them.
- Have the organic matter content measured when you have a soil test sent out.

The following could be included in the course as an extra handout, a take-home lesson, or a field-based outdoor activity if time is short.

Testing Your Soil for Nutrients, Organic Matter and Contaminants

If you detect signs of trouble that aren't solved by the usual techniques or your garden isn't performing as well as it should, you might want to test the soil.
The most common tests are for:

- pH
- N-P-K (nitrogen-phosphorus-potassium)
- magnesium
- calcium

Some labs test for organic matter and nutrient-holding capacity. Labs may also test for possible soil contaminants, such as lead.

When to test:

- Test once a year from the same lab so that you can compare results over time. You are most likely to get recommendations for your specific soil conditions from labs based closed to home.
- Test in the summer. This is when nutrient availability should be highest, so you won't add more fertilizer than is necessary. Also, you will be able to spread rock powders, like lime, in the fall or winter.
- When you send in your soil test, make sure the lab knows to recommend organic amendments rather than chemical fertilizers and amendments. Organic amendments generally work more gradually then chemical ones, so good planning and timing are important. (Some examples include dried blood and fish emulsion for N; phosphate rock and bone meal for P; and seaweed and wood ashes for K.)

pH

- Measures the relative acidity and alkalinity of the soil solution
- Scale from 0-14, 7 is neutral, <7 acidic, >7 alkaline
- Nutrient availability, soil microbial activity and soil structure are all affected by pH
- Most vegetables grow best in a **slightly acidic soil with a pH of 6.8**. 6.0 to 7.0 is fine for most crops

	pH Test You can do a quick pH test using litmus paper. These home kits are very inexpensive. Garden supply companies and plant nurseries often carry them. 1. Follow the directions on the package to mix up a slurry of soil and distilled water. *2.* Insert the test strip and match it to the color chart provided to find the pH. *Each student may now test their sample for pH.*
Group Activity: Reading a Soil Test 10 min	*Look at copies of soil tests from Bronx gardens (or other sample soil tests).* In groups of 3, look over past soil tests for Bronx community gardens. Be prepared to share with the class (*write the following on the board*): • Soil pH: Is it high, low or neutral? • Organic matter content (%): Is it within the desired range? • Lead level: Is it high, medium or low? • Are there sufficient levels of nutrients (N, P, K, Ca, Mg, S)? • What are the recommendations for fertilizer?
Lecture 8 min	**Soil Contaminants** *Give out Soil Contaminants handout.* Soil contamination comes from a variety of sources including garbage dumps, sewage sludge, treated lumber, pesticide residues, old building materials that may contain peeling paint, fires (particularly burning of garbage, building material, and other synthetic substances), and air and water pollution. Property located near high-traffic areas may have more contaminants in the soil, as may sites that had former industrial or commercial use. You can reduce the risk to your own health and the health of those who use your garden in a number of ways. First, identify the problem. The best clue to determining whether you have soil contamination is to investigate the history of your land and nearby properties. What were they used for in the past? What chemicals may have been used there? Neighbors, local libraries, historical societies, and the county clerk's office may have records and historical maps. Searchable databases such as nyc.gov/acris and propertyshark.com may also be useful. **Soil Testing:** If you suspect the presence of harmful contaminants in your soil, you can have a special test done as routine soil tests do not check for these. Soil testing can help answer questions and concerns about possible contaminants. Visit Cornell Nutrient Analysis Laboratory for instructions (http://cnal.cals.cornell.edu). Brooklyn College's Environmental Sciences Analytical Center also offers soil and plant tissue testing for heavy metals (www.brooklyn.cuny.edu/pub/departments/esac/1535.htm). Although inorganic substances such as heavy metals occur naturally in soils, elevated levels can be toxic. The most common heavy metal contaminants in soils include lead, cadmium, and arsenic; these may stay in the soil for a long time, and certain soil conditions, such as a shortage of organic matter, might cause the chemicals to be more easily taken up by plants. Organic contaminants, such as some pesticides or polycyclic aromatic hydrocarbons (PAHs) may also be of concern and require more specialized testing in order to detect them. Lead is one of the most widespread soil contaminants. It may come from past automobile exhaust (when lead was used in gasoline) or flakes of lead-based paint. Lead is especially of concern to children under age

six and pregnant women.

Although there is no clear standard for what is considered "safe," various agencies have recommended guidelines. If contamination levels exceed these guidelines, it is important to limit exposure to the soil, especially for children.

Exposure to soil contaminants[3]
People can sometimes be exposed to soil contaminants by handling soil, accidentally breathing in or eating soil particles, or eating vegetables.

- The main health hazard with heavy metals is direct contact with the soil. If children play in soil that contains lead, they can inhale the lead as dust. Young children may also eat the soil.
- Contaminated soil particles may also stick to edible parts of vegetables, particularly leafy and root vegetables. And, although it's likely to be much less of a threat to human health, sometimes heavy metals may be taken up by plants in the garden soil.

Best Gardening Practices[4]
If you suspect or know that your soil contains contaminants, the following best practices will limit your contact with contaminants:

- Add organic matter such as compost to reduce the availability of metal contaminants in your soil. Organic particles will bind with metals and help prevent them from being absorbed by your plants. Adding organic matter also physically dilutes the contaminants.
- Keep pH levels close to neutral (between 6.5 and 7) and make sure drainage is adequate to help to ensure that the contaminants don't move in your soil. Mulch and use cover crops to keep dust levels down and organic matter levels up.
- Grow crops in raised beds (avoiding pressure-treated or previously painted wood) or containers filled with uncontaminated soil. This is especially important if you suspect higher levels of contaminants.
- Keep play areas and pathways covered in mulch to reduce exposure to the soil. Use a barrier such as landscape fabric to keep the mulch separated from the soil underneath.
- Keep an eye on young children to make sure they do not put soil or objects with soil in their mouths.
- Wear gloves when gardening and thoroughly wash hands after gardening.
- Thoroughly wash and/or peel vegetables and fruit before eating, especially leafy and root vegetables.
- Avoid bringing soil into your home by removing it from garden tools, vegetables, and clothing as carefully as possible.

A great resource for more information (fact sheets, best practices handouts) on soil contaminants is the Cornell Waste Management Institute's Department of Crop and Soil Sciences at: http://cwmi.css.cornell.edu/soilquality.htm

[1] *New York City Master Composter Manual*, 2012. Reprinted with permission from the NYC Department of Sanitation's Bureau of Waste Prevention, Reuse and Recycling.

[2] Gershuny, Grace (1997). *Start with the Soil*. Rodale Press.

[3] Cornell Waste Management Institute's Department of Crop and Soil Sciences. (February 2014). Retrieved from: http://cwmi.css.cornell.edu/sourcesandimpacts.pdf

[4] Cornell Waste Management Institute's Department of Crop and Soil Sciences. (February 2014). Retrieved from: http://cwmi.css.cornell.edu/sourcesandimpacts.pdf