On-Farm Composting Toolkit

For urban farms and community gardens in Alameda County

STOPWASTE

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Urban farms and community gardens grow two things: plants and soil. Building healthy soil is fundamental for growing healthy fruits and vegetables and supporting healthy communities. The benefits of building soil extends to farms and gardens that raise animals and grow plants for fiber, and is particularly vital for people who work with urban soils, where the impacts of development may have left behind degraded soils in need of repair and replenishment. Using compost builds fertile soil that is rich in organic matter, dark and wonderfully crumbly, teems with life, holds onto moisture, and drains well. Using compost also helps sequester carbon by stimulating healthy plants to pull carbon dioxide out of the atmosphere and storing carbon in plants, roots, and amongst fungi and bacteria deep in the soil.

On-farm compost compared with commercial compost.

On-site composting offers many advantages for urban farms and community gardens. Purchasing compost from vendors can be expensive and requires transportation in bulk. When farmers make their own compost they control feedstocks and compost quality, and eliminate greenhouse gas emissions from municipal collection, commercial composting, and delivery.

How to Use this Toolkit

The goal of this toolkit is to provide a practical step-by-step approach for urban farms of any scale to either start on-site composting or evaluate and improve an existing system. Composting requires skill, time, planning, and maintenance–approach it like any other aspect of operating an urban farm or community garden. All sites are different in terms of space, feedstocks, equipment, organization of people, and experience with making and using compost. This toolkit can help farmers adapt and evolve on their path towards becoming master composters.

1. Learn More about Composting

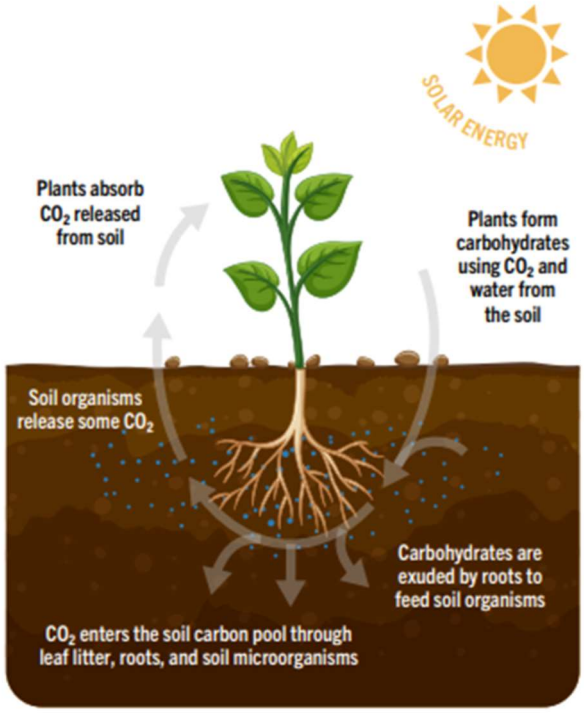
Composting is a satisfying way to turn organic waste into a dark, crumbly, sweet-smelling soil amendment. Decomposition naturally occurs when microorganisms (fungi and bacteria) and invertebrates transform organic matter into compost. All organic material will eventually break down, but by creating the right conditions the process can be accelerated. Four basic elements are necessary for thermophilic, or hot, composting. These "Big Four" are: browns, greens, air, and moisture content (all of which are necessary for microbial life). The relative lack or abundance of each of these elements determines the speed of decomposition and the quality of the finished compost.

Browns are dry materials such as fallen leaves, twigs, prunings, straw, wood chips, and sawdust that are the source of carbon for the microorganisms. Greens are fresh, soft, and moist materials such as grass clippings, food scraps, crop residue, and herbivore manures that are the source of nitrogen. Microorganisms need a ratio of about 30 parts carbon to 1 part nitrogen. If the carbon to nitrogen ratio (C:N) drops below 20:1 some of the nitrogen will leach out of the pile as ammonia or nitrous oxide, and it may smell rotten. If there is too much carbon, a C:N ratio above 40:1, the pile will take a long time to break down and may not get hot enough to kill weed seeds and plant pathogens. A good rule of thumb for creating a favorable C:N ratio is to mix equal parts by volume of browns with greens and make adjustments based on field observations.

The microbes that make hot composting happen need a steady supply of oxygen and sufficient moisture content. Air can enter a pile in the spaces between twigs, wood chips, and other large pieces of compostable material and when the pile gets turned. If the oxygen supply is cut-off or restricted the composting process will slow down and the pile may become smelly. The ideal moisture range for microbes is within 40 to 65%, or about as moist as a wrung out sponge. If the pile dries out microbial activity will slow down or stop, but if it gets too wet there won't be enough oxygen available for hot composting.

Compost and Carbon Farming

Making and using compost is a powerful carbon farming practice. Carbon farming practices help reverse climate change and encourage plants to maximize the amount of carbon dioxide they draw from the atmosphere and store deep in the soil. Plants naturally absorb carbon dioxide from the atmosphere during growth, release oxygen to the



The Carbon Cycle in soil ecosystems.

air and convert the carbon into sugars, and release the sugars from their roots to nourish the soil microorganisms that in turn provide roots with plant nutrients. When the microorganisms and plants die they break down and build up the carbon pool in the soil. Feeding your soil with compost accelerates this process by encouraging microbial activity and plant growth.

2. System Planning

The key factors in system planning are to identify feedstocks, locate an appropriate site, and select a composting system.

Feedstocks

Every farm or garden produces different types of waste that can be composted.

Common feedstocks:

Greens/High-Nitrogen

- Fruit and vegetable trimmings & waste
- Fresh crop residue
- Grass clippings
- Herbivore manures: e.g. goats, horses, chickens, pigs
- Weeds that haven't gone-to-seed

Browns/High-Carbon

- Leaves
- Chopped, woody prunings
- Pine needles
- Sawdust from untreated wood
- Animal bedding
- Straw
- Wood chips

For the Green Bin

These materials are hard to compost on-site and should go in the green bin:

- Weeds that have gone-to-seed
- Highly invasive weeds: e.g. Bermuda grass, crab grass, nut grass, English and Algerian ivy, and ice plant
- Meats, bones or fish
- Dairy products or greasy foods
- Large amounts of food-soiled paper
- Compostable plastics, even if they are certified "compostable"

For the Landfill Bin

These materials should never be composted on-site or placed in the green bin:

- Sawdust from plywood or treated wood
- Carnivore and pet feces: e.g. dog, cat

Cover crops build healthy soil and make excellent nitrogen-rich feedstocks.

Master Composter Tip: Problematic Browns

Some browns can be challenging to compost and should only be used in moderation. For example, pine needles are evergreen and resist decomposition, and sawdust is extremely fine and can plug up and restrict airflow in a pile. Adding large amounts of problematic browns will slow the process down.

- Palm fronds and poison oak
- Poly-coated paper: e.g. milk cartons, some takeout containers
- Sod (can be flipped upside-down and sheet mulched over instead of landfilled)

Develop a Compost Recipe. Microorganisms need carbon and nitrogen in the right ratio in order to thrive, about 30 parts carbon to 1 part nitrogen (30:1). All feedstocks contain varying amounts of both carbon and nitrogen, and a general guideline is to mix equal parts of brown, high-carbon material with green, high-nitrogen material. It's a good idea to think through the types and amounts of organic waste generated on-site and what feedstocks may need to be supplemented from off-site.

- What are the main feedstocks produced on-site?
- What feedstocks must be supplemented from off-site? For example, many farms have a lot of wet, green crop-residue and will need to find a source of brown high-carbon material to balance it out, such as wood chips, or straw.
- Build active piles as soon as green and high nitrogen feedstocks become available, e.g. near the end of crop harvests. Green materials lose nitrogen and moisture over time and quickly convert to dry brown materials if not immediately composted. Dry brown materials can be stored for longer without a loss in quality.
- When removing plant material during weeding or harvesting, put high-value feedstocks in a special drop off zone near the compost area that is separate from low-value feedstocks, and put problematic materials straight into the green bin to prevent contamination.
- Be careful when taking certain feedstocks from off-site, such as straw treated with pesticides, manures with hormones or gravel, or wood chips with diseased material.

Master Composter Tip: Planning for Materials

Estimating how many cubic feet or gallons of compostable materials are produced over time can help with system planning. How many 3ft by 3ft by 3ft bins could be filled after harvest? What does the farm produce more of, browns or greens? What needs to be supplemented?

Check with your local jurisdiction's recycling department before gathering any feedstock from off site. Collection of organics may violate the local franchise agreement with your city's waste hauler.

Stockpile browns near your bins until fresh greens become available.

Site and Equipment Considerations

When planning a compost operation take the time to identify an appropriate site and make sure the right tools and equipment are available.

- Choose a location with enough space to store feedstocks, make and turn piles, cure compost, and store finished compost. Ideally, the compost area will be near productive fields for efficiency.
- Wheelbarrows and garden carts will be needed to move and handle a large amount of materials, and large operations will benefit from a tractor with a front-end loader.
- Turning piles is an important and fairly labor intensive part of hot composting, and it's a good idea to think through who will perform this time sensitive task. Make sure there are enough trained workers and volunteers available to help.
- Woody materials like twigs, leaves, and small branches will need to be broken down into small pieces. A chipper shredder, if available, can break this material down fast, but hand tools like pruning shears or machetes can also work.
- Composting doesn't require a lot of specialty equipment, but farms will need a compost thermometer to track pile temperature, and a sturdy screen for sifting finished compost.
- Keep a buffer between the compost site and natural drainage areas like streams and rivers. Also, make sure there is adequate drainage so that piles do not get flooded by rain or surface runoff.
- Compost piles attract rodents, especially when food waste is involved. Farms located in urban areas might need to use rodent resistant bins.

A compost thermometer measures the temperature of the center of the pile.

Master Composter Tip: Dealing with Invasive Weeds

If invasive weeds contaminate the compost area they can be inadvertently spread all over the garden when the compost is applied. Hot composting can kill weed seeds but only after exposure to temperatures of at least 145 °F for 1 to 2 weeks, and piles must be turned sufficiently to expose all seeds to the high temperatures near the core of the pile. Bermuda grass can be a huge problem, both when it spreads into the compost site and when used as a feedstock.

Take precautions to prevent weed contamination:

- Weeds that have gone to seed, or highly invasive weeds that spread (e.g. Bermuda grass) should be placed in the green bin and NOT composted on-site.
- Use physical barriers to keep Bermuda grass away from compost sites. Build piles on top of impermeable surfaces such as concrete, or on thick layers of cardboard.
- Compost piles can be built where Bermuda grass or other entrenched weeds have been dug out, hand pulled, and suppressed with sheet mulch.
- Keep areas planted with cover crops that can successfully compete with weeds.

Choose a System

- **Single bins** are either store bought plastic bins or built by hand with wood. Single bins need to be filled up in one batch for hot composting. They are rodent resistant and don't take up much room (3ft by 3ft footprint), but have a limited capacity and are not always easy to turn. Refer to the Composting Resources section for schematics.
- **3-bins and bunkers** are larger bins that can efficiently handle more material. It's a good idea to leave one bin empty so that piles can be easily turned by unloading them into the empty bin. The minimum footprint is 3ft by 9 ft. These bins are custom made and require some building skills for construction. Refer to the Composting Resources section for schematics.

A plastic, rodent-resistant single bin.

A hand-built 3-bin system.

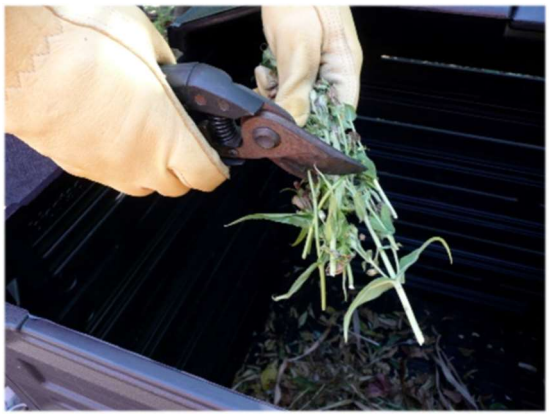
Large piles require a front loader for turning.

- **Piles and windrows** can handle large amounts of feedstock. To create the right conditions for hot composting, piles should be built in a single batch, so aim to build them when there is enough material for at least a 3ft by 3ft by 3ft pile. If there is too much material for one pile then a windrow can be built, which is basically a pile that is 4 ft tall by 4 ft wide and then as long as needed to use up available feedstock. Piles and windrows are easy to turn and eliminate the need to purchase or build bins, but they take a lot of space and don't protect against rodents, rain, and weeds.
- **Compost tumblers** are NOT recommended. Most tumblers inhibit hot composting by over aerating and drying out materials, are too small in dimension for hot composting, lack capacity for the amount of material generated on urban farms, and are typically quite expensive. They are advertised for their easy-to-turn design, but in actual practice they don't thoroughly mix materials. And because they are lifted off the ground, they exclude a range of invertebrates that are vital decomposers during the cold stage of composting.

3. How-to Compost

Building a Pile

Start a new pile when there is enough material to fill a bin completely, or to build a windrow about 4ft tall by 4 ft wide by 6 ft long. Taller piles encourage hot composting by increasing thermal insulation and decreasing evaporation. Timing should be based on the availability of green high-nitrogen materials since they tend to lose nitrogen and moisture over time, while dry high-carbon materials can be stored for longer. Browns can be stockpiled in a pile, bunker, or empty bin in the compost area so that they are readily available when it's time to build a new pile.



Chopping material is time consuming, but drastically speeds up decomposition rates.

Prepare your feedstock. Chop material between 4" to 6" either with hand tools, e.g. pruning shears or a machete, or with a chipper/shredder. If a chipper is used, only chip about 70% of incoming brown materials and leave the remaining 30% un-chopped. This mix of small and large pieces provides enough structure for good airflow and enough small pieces that will break down fast and help with moisture retention. If chipping size is adjustable, aim for no smaller than 4"pieces because chipping materials too finely can impact pile structure and inhibit air flow.

Layer browns and greens. Feedstocks need to be layered and mixed to combine carbon and nitrogen in a favorable ratio, and to provide enough structure for air flow. When building a new pile, aim for a recipe of 1 part brown, high-carbon material to 1 part green, high-nitrogen material. Always start with a layer of thicker woody brown pieces on the bottom to encourage aeration, and then add alternating 4" to 6" layers of greens and browns, mixing the layers together with a garden fork. Top the pile with a layer of browns to retain moisture.

Always finish with a layer of browns.

Master Composter Tip: Use Enough Browns

When building a new pile, consider that green materials decompose quicker than brown materials. A pile started with too many browns is forgiving because green materials can be added later and will *quickly* decompose. On the other hand, a pile started with too many greens takes longer to finish because brown materials can be added later, but they will *slowly* decompose.

Maintaining a Hot Compost Pile

Compared to cold static piles, hot composting produces compost faster, takes up less space, is more likely to kill weed seeds and plant pathogens, and is less likely to produce foul odors. The most important conditions for hot composting are aeration and moisture content. Check the Troubleshooting Guide in the Resources section for more maintenance information.

Lifecycle of a compost pile. The level of microbial activity changes as a pile decomposes over time, leading to natural rises and dips in pile temperature. During the first month or two when microbial activity is highest, the compost pile should sustain high temperatures ranging between 100 to 150 °F. As most of the nutrients are consumed and microbial activity slows down, a hot pile will gradually cool down towards 100 °F and even cooler. For hot piles, the entire lifecycle usually takes between 3 to 6 months to complete, while cold piles can take 12 months or even longer.

Monitor temperature. Temperature is the best indicator that everything is working, and it is very easy to measure. In the first couple of weeks a healthy compost pile will get very hot (ideally in the 120 to 140 °F range). If the temperature is below this, it's a sure sign that the new pile needs correction.

Moisture content. If the pile dries out microbial activity will slow down or stop, or if it's too wet there won't be enough oxygen available for hot composting. The ideal moisture range is between 40 to 65%, or about as moist as a wrung out sponge. Unfortunately, there isn't an easy way to measure moisture content, but you can make an estimate by reaching 12 to 18 inches deep into a pile to grab a handful of material. Squeeze tightly: if you see a few drops of water between your fingers, or a sheen of moisture is visible after opening your hand, you are within the ideal 40 to 60% moisture range. If water runs down your arm (>65%), it is too wet and requires light turning. If the material feels dry, does not form a ball when squeezed, or a sheen of moisture is NOT visible after you open your hand (<40%), add water. Refer to the US Composting Council's sheet "Measuring Compost Moisture by Look and Feel" in the Resources section.

Moist as a wrung out sponge.

Monitor for odor. Another tool that is helpful for monitoring the composting process is the human nose. Strong foul odors are a sure sign that something is off, usually too much moisture which deprives the pile of oxygen. A smelly pile could also be a sign that the C:N ratio is too low, in other words there is too much wet green material and not enough dry browns. Adding dry brown material can help correct the situation by soaking up excess moisture and adding structure.

Turn the pile as needed. If the pile is too cold (below 100 °F in the first month), hot (above 150 °F), wet, or smelly, it needs to be turned. Composting requires large amounts of oxygen and if there isn't enough the process slows down or stops. Turning a pile adds oxygen and mixes the material together which helps it break down more completely. If the pile is within the ideal temperature and moisture range there is no need to turn it.

Turning schedule. The turning schedule for hot composting should adapt as a pile matures and the compost process slows down. Keep in mind that this timing will vary from system to system depending on pile size and type of material, and will also need to be adjusted based on available labor.

Week 1:	Turn every other day, unless temperature is 130 to 140 °F then there is no need to turn.
Week 2-4:	Turn twice per week, unless temperature is above 100 °F then there is no need to turn.
Week 5-8:	Turn once per week, temperature may hover near ambient air with short spikes above 100 °F.
Week 9 and beyond:	Turn every other week, temperature should be near ambient air temperature. Begin to pull out and set aside heavier, woody materials.

How to turn a pile. Piles can either be turned by hand with a garden fork or with a tractor that has a front-end loader. Make sure to thoroughly mix all materials and add water if necessary. When turning with a front-end loader, a sturdy push wall is recommended. After turning, a hot pile will drop in temperature, but will heat back up again after a couple of hours.

Stackable bins break apart to assist turning.

Turning with a front loader is easier with a reinforced push wall at the back of the bunker.

Master Composter Tip: Two Methods for Hand Turning

Pile turning is one of the most important parts of successful hot composting. Over the course of a pile's lifecycle, it's a good idea to turn it 2 or 3 times using the *thorough method*, but farmers can use the *easy method* to quickly add oxygen and adjust temperature.

Thorough Method. Scoop up the top 1/3 of the pile with a garden fork, rotate to the left and put this material on a tarp within reach of your tool (this will become the bottom of the pile). Next, pick up the middle 1/3 with a fork, rotate to the right, and put it down within reach. Scoop up the bottom of the pile, rotate again to your left and put this material onto what was the top (this will become the middle of the pile). Rotate to the right and grab what was the middle of the pile and put it on top. Use the garden fork to constantly mix, stir, and combine materials throughout this process.

Easy Method. Poke a garden fork deep into the pile, lift the material a bit, and wiggle the fork. This aerates and lightly mixes the pile, and only takes a couple of minutes!

Document the process. The Compost Pile Monitoring Record in the Resources section can be used to track maintenance and can help improve results by recording changes over time (e.g. temperature, consistency of the material, and organisms present).

Keep the bin covered. Keep compost bins covered to help with moisture retention and reduce weed seed contamination. Consider building a hinged wooden lid for each individual bin that opens backwards. Simpler options like tarps or cardboard can be used but will provide less protection from the sun and rain, less aeration near the top of the pile, less protection from pests, and require more ongoing effort. Open windrows and piles can remain uncovered, however it's a good idea to cover them with a tarp when it is rainy, windy or extremely hot.

Identifying Finished Compost

During the first month or two of intense microbial activity the pile will get very hot (120 to 140 °F). As the bacteria and fungi consume most of the nutrients, the pile will reduce in size and gradually become a cold pile. As the pile cools, invertebrates such as worms, pill bugs, beetles, centipedes and millipedes become more active and finish chopping and breaking down bulkier, brown materials. It is important to give these little guys a couple of months to finish their work. After 3 to 6 months, when the majority of the feedstocks are unrecognizable and the compost is predominantly dark, crumbly, earthy material, the decomposition process is complete and the compost is finished. Some woody pieces may still be present in finished compost.

Screening Compost

Screen out and set aside larger pieces of woody material for a new pile. A sturdy screen can be made by attaching 1/2 inch hardware cloth to a 2 by 4 frame. Screens can be built to securely rest on top of a wheelbarrow. Add compost to the screen until it is full, then use a flat bladed shovel to push the finished compost through the screen into the wheelbarrow. The large woody pieces will stay on top of the screen and can be added to a new compost pile.

Resting a screen on top of a wheelbarrow.

Spare single bins are ideal for curing and storing compost.

Curing Compost

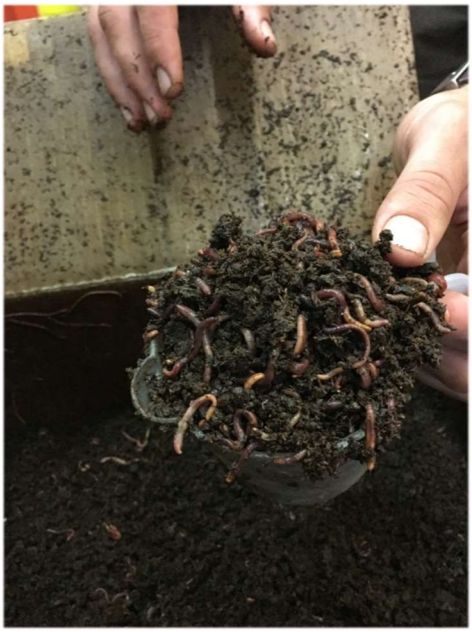
Move the finished compost onto a tarp or into an empty bin and let it sit and cure undisturbed for 1 to 2 months. Cover with a tarp or bin cover to prevent weed seeds from blowing into compost. Curing stabilizes organic matter, makes nutrients more readily available to plants, and gives invertebrates a chance to disperse. Applying uncured compost to soil may stress plants.

4. Worm Composting

Vermicomposting uses worms to digest feedstocks and create worm castings, and is very different than hot composting. Worm castings are an excellent soil amendment that can be produced in about half the time it takes to finish hot compost, however, worm composting requires greater attention to detail and more troubleshooting than a hot compost pile. Worm composting operations range from small kitchen bins stocked with a pound of worms, to mid-sized bins that are a good fit for urban farms, and all the way up to highly mechanized systems with millions of worms.

Learn More about Worm Composting

The star of the worm composting show is *Eisenia fetida,* more commonly called the "red wiggler". Red wigglers breed faster and are more robust than other earthworms, qualities that make it the worm of choice for the majority of commercial operations. Despite being relatively hardy, red wigglers should be treated with care because they are delicate creatures. They breathe through their skin, which must always be kept moist, and can only survive within the moderate temperature range of 40 to 90 °F. If exposed to direct light they can become paralyzed and will lie motionless, allowing the light to gradually dry their skin until they can no longer breathe.



Red wigglers in worm castings.

It takes skill, patience and practice to master worm composting, but worm castings are such an excellent soil amendment that it is worth the investment. Worm castings enhance soil structure, improve nutrient and water retention, and help plantsresist pests and disease. Compared to hot compost, worm castings typically contain more nutrients (especially nitrogen), are better at helping plants take up available nutrients, host a larger and more diverse population of microbes, and only take about half as much time to produce.

System Planning

Ripped newspaper is a safe and widely available option for worm bedding.

Bedding

Bedding provides the media where the worms live. It must be loose, porous, and moist enough for the worms to freely wiggle around and breathe. It also keeps the worms from getting too hot or too cold, and protects them from direct sunlight. Don't use materials that contain harmful chemicals, such as glossy magazines. Only use stable, high carbon materials as bedding or the bin will start hot composting and become too warm for the worms to survive.

Common Bedding Materials:

- Black and white newspaper ripped into one inch strips
- Shredded corrugated cardboard
- Dry leaves
- Finished compost
- Straw
- Wood chips

Feedstocks

Different feedstocks should be mixed to produce a favorable C:N ratio of about 30:1, and to provide enough structure for air to flow through the bin. A C:N ratio of 30:1 encourages microorganisms to envelop the feedstocks which provides a major source of the worms' nutrition. Chopping the feedstocks up into smaller pieces makes it easier for the worms to eat and helps speed up the process. Add about one pound of food per square foot of bin on a weekly basis.

Do Feed Your Worms:

- Fruit and vegetable scraps
- Shredded paper
- Egg shells
- Coffee grounds and filters
- Tea bags

Don't Feed Your Worms

- Grains, beans or breads
- Meat, bones, or fish
- Oily or salty food
- Dairy products or grease
- Citrus peels

Pull back the top layer of bedding before feeding worms.

Start small until you're ready to transfer the worms into a larger container.

Build a Worm Bin

Anyone with basic building skills can make a worm bin. Retailers do offer plastic worm bins, but these are only designed to handle the small amount of food scraps typically produced in a residential kitchen and aren't suitable for farm use. Beginning worm composters might want to learn the basics using a plastic kitchen bin before they get started on a larger scale worm composting project. Bins must be strong enough to hold the bedding, worms, and feedstocks; have adequate drainage for excess moisture to escape; and allow a steady flow of oxygen. They are often built out of wood, cinder blocks, or by adapting plastic containers. Plywood and untreated wood can be used but will eventually rot. Treated wood should not be used as it contains chemicals harmful to worms. Rot-resistant woods like

cedar or redwood contain compounds that can irritate worms, although some farmers report using these materials without any problems.

- Place worm bins in a shaded area or cover them with a roof and/or lid so they don't dry out or get too hot.
- A rodent resistant bin helps control pests, especially when food scraps are involved.
- A solid well-latched lid will prevent birds and moles from eating the worms.

How-to Worm Compost

Put about 6 inches of bedding at the bottom of the bin and then add about 1 pound of worms per square foot of surface area. If a new bin gets started with too few worms, it will take a very long time for the population to grow large enough to successfully process a significant amount of feedstock. For a list of vendors who sell *Eisenia fetida*, check the Resources section of this guide. Feed the worms by adding a 1.5" thick layer of feedstocks on top of the bedding. To avoid fruit flies and odors, keep the food covered with a thin layer of bedding. The biggest mistake beginning worm composters make is overfeeding. One feeding per week is enough for most worm bins. Feedstocks contain nitrogen, and if they accumulate in the bin because of overfeeding it could trigger hot composting causing the bin to get too hot for the worms. Allow the worms to set the feeding schedule and pay attention to what they eat and how much they can handle.

Maintaining the Worm Bin

Monitor the bin weekly to ensure that the worms are thriving.

- Check moisture content and that the worms' skin is slick and moist. Keep the moisture content in the 65 to 80% range, which is wetter than a hot compost bin. Check the US Composting Council's sheet "Measuring Compost Moisture by Look and Feel" in the Resources section.
- Observe the worms' behavior, if they try to escape or clump together near the surface it's a sign that conditions aren't ideal. See the troubleshooting section for more information.
- A healthy worm bin should smell sweet and earthy, so keep a nose out for rotten or sour odors.
- Measure temperature, particularly when it's cold or hot outside. Worms thrive in temperatures between 60 and 80 °F, and can survive within a range of 40 to 90 °F. Bins can be cooled down by increasing shade, adding insulation, and by not adding feedstock to parts of the bin so worms can go to these areas to cool down. On the other hand when it's cold, insulate the bin by placing straw on the outside to keep it a little warmer, and by adding more food to parts of the bin which will give the worms a chance to warm up.
- Compost critters such as sow bugs, pill bugs, colembola, and beetles are beneficial and will not harm the worms.

Harvesting Worm Castings

After about a month, once worm castings start to accumulate and bedding starts to break down, it will be time to harvest. The trickiest part is separating the worms from their finished castings. Sideways harvesting encourages the worms to move into a new area and leave behind the finished castings along with some bedding and undigested feedstocks. Farmers can build bins with temporary barriers that can be moved to open up a new zone for the worms to move into. Worms can be encouraged to move by not adding more food to the old part of the bin, and preparing a new area with fresh bedding and food. Be patient, it will take several weeks to a month for the worms to move out.

A quicker option is to scoop up the top 6 inches of material where the worms tend to congregate, and put it in a tote or wheelbarrow. The finished castings in the bottom of the bin can then be scooped out

and screened to remove any remaining worms, bedding, or undigested feedstocks. StopWaste has been teaching home gardeners the cone/pile method of harvesting for decades, a technique that is also effective at the mid-size scale of an urban farm. The material in the bin (worms, bedding, castings and all), is scooped out and placed on top of a tarp in a series of cone shaped piles. Sudden exposure to sunlight causes the worms to wiggle down deep into the piles and the finished castings can be scooped off the top. After harvesting, add a 6 inch layer of fresh bedding to the bin, put the worms back in, and add some food.

Storing Castings

It's best to use worm castings as soon as possible since they teem with beneficial microorganisms. If storage is necessary then use a well ventilated container that allows for a steady flow of oxygen, and keep them moist and out of direct sunlight.

5. Co-composting with Biochar

Biochar is a charcoal product made from a process called gasification or pyrolysis. Pyrolysis is the heating of a feedstock to temperatures of 500 to 1,000 °F in the absence of oxygen. It is not incineration or burning. Biochar can be made from many different feedstocks, including wood, straw, green waste, food waste, and manures. Depending on the feedstock, the biochar will have different properties, but typical biochar contains high carbon and low ash content, and has incredibly high surface area due to its porosity. When present in a compost pile, biochar behaves as an ideal environment for microorganisms to proliferate. For this reason, some composters have observed many benefits when co-composting with biochar including reduced pile odors, extended periods of hot pile temperatures, and improved moisture retention and aeration. And because it remains chemically stable for hundreds to thousands of years, biochar provides long-term carbon storage in soils.

Best practices for co-composting with biochar include mixing biochar throughout a newly built compost pile and aiming for a quantity of 10% water-soaked biochar by volume, or roughly four 5-gallon buckets for a single bin. Biochar quality may be highly variable – biochar produced at temperature of 800 °F and above is ideal to use in composting because it facilitates nutrient exchange better than biochar produced at lower temperatures. Experiments have shown that compost co-composted with biochar results in better plant performance than blending biochar into compost after composting, compost alone, and biochar alone, in that order.

Co-composting with biochar is not a necessity, but is a great option for struggling composters because it makes the composting process more forgiving.

6. Using Regular Compost and Worm Castings

Compost improves fertility, soil structure, nutrient and water retention, and encourages beneficial microbial and fungal mycorrhizal activity. In addition, adding compost to soil helps reverse climate change by increasing the amount of carbon dioxide absorbed by plants and stored deep in the soil in roots and amongst soil microorganisms. Compost does not need to be worked into soil–consider no-till as a practice when using compost! A note on worm castings: they are so packed with nitrogen and other nutrients that they can burn plants, and should be used in smaller amounts than regular compost.

Here are some of the best ways to use finished compost:

Practitioners of no-till farming sidedress with compost, and allow rain and invertebrates to work it into the soil.

Topdressing for new beds. For establishing new planting beds in compacted soil, double dig a 2" to 4" layer of **regular** compost into the soil. After this initial heavy application, switch to sidedressing as needed to keep soil healthy and fertile.

Sidedressing for existing beds. Spread a 1/2" to 2" layer of **regular** compost, or a 1/4" layer of **worm** castings, on top of the soil around existing plants at least once a year. Sidedressing can be done anytime, and improves soil fertility and reduces watering needs.

Worm castings dilution. Place a large handful of worm castings into a colander, and place the colander over a 5 gallon bucket. Use a hose to run water over the castings, allowing them to break apart and dilute with water in the bucket. The dilution should be the color of weak tea. Use to water your plants.

Potting Mix. Sifted compost can be added to potting mix to make a rich, loose potting soil for starting seedlings from scratch. Adding compost to potting mix increases moisture storage and provides a variety of nutrients not typically supplied in commercial fertilizers or soil-free potting mixes. NOTE: Do not use pure compost as a planting medium; it should always be mixed with other materials.

Amber-colored compost tea being poured into a sprayer.

Recipe for starting seedlings:

- Sift compost through a 1/2 inch or smaller mesh.
- Mix 1 part sifted **regular** compost, and 3 parts potting soil, or…
- Mix 1 part sifted **worm** compost, and 5 parts potting soil

Compost Tea. Compost tea is a liquid fertilizer that nourishes plants and can protect them from disease. To make compost tea put a handful or two of compost (either worm or regular compost) into a 5-gallon bucket, fill the bucket with water, add 2 tablespoons of molasses to feed the microbes, and stir until the ingredients are mixed. Let the tea steep for 3 or 4 days, stirring several times a day to add oxygen.

Another option that improves compost tea quality is to brew with an aquarium bubbler rather than by hand stirring. A bubbler constantly adds oxygen, which helps microorganisms thrive. The process is similar to the hand stirring method described above: put a handful or two of compost into a 5-gallon bucket, fill the bucket with water, add 2 tablespoons of molasses to feed the microbes, and set up an inexpensive aquarium air pump in the bucket to aerate the tea while it steeps for 3 to 4 days.

Compost tea should be used within 24 hours after it is finished brewing. Pour the contents of the 5-gallon bucket through a mesh kitchen strainer (to remove sediment) into a watering can, dilute to a light amber color, and water around plants. Compost tea can also be sprayed on plant leaves to protect them from disease. The tea should be filtered through cheesecloth to remove sediment, added to a garden sprayer, and sprayed onto plant leaves.

Note: the liquid that comes from your worm bin is not compost tea, but a leachate that can be harmful to your plants.

7. Purchasing Compost in Bulk

While on-farm composting produces your own high quality soil amendment, there are always circumstances where buying compost in bulk from a producer or vendor will be required. If you are establishing new crop rows or beds and expanding your production, you may not produce enough compost onsite to cover all your needs. While purchasing compost in bulk is a safe and cost-effective option in California, you should always make these considerations when selecting a compost vendor and choosing a bulk compost product.

Always inspect compost before a delivery truck empties.

Purchased bulk compost is safe to use when it is:

- Mature, well decomposed, stable and weed free. A bulk compost pile that is steaming is not fully mature or cured, and should sit for at least a couple of weeks before use.
- Made from the following acceptable feedstocks: green material, vegetative food material, and/or agricultural materials.
- Containing no substances toxic to plants, and no visible glass and plastic contamination.
- Dark brown to black in color.
- Giving off acceptable odors of soil-like, forest-like, and moldy.
- Free of unacceptable odors of ammonia, rot, garbage, and sourness.
- Not resembling the feedstock (original materials from which it was derived). Small amounts of woody material is acceptable, but the compost should not look as woody as a mulch.
- Certified by CDFA as an Organic Input Material (OIM), and/or be certified by OMRI (Organic Materials Review Institute), and be produced by a permitted facility and participant of the US Composting Council's STA (Seal of Testing Assurance).

Contact a compost producer or vendor ahead of time to ask questions and ensure these standards are met, and ask for lab test evidence of the maturity and Carbon to Nitrogen ratio of their compost. The C:N ratio of mature compost should be near 10:1, and should not exceed 20:1. Upon delivery, inspect compost in the truck before it is dumped – you can always send back a bulk compost delivery if it does not meet your standards.

Use the Lawn to Garden Compost and Mulch Vendor Marketplace. Found in the Tools and Resources section, the Marketplace can help you find vendors closest to you in order to minimize shipping costs.

8. Keep it Going

Take steps to institutionalize the on-farm composting program so that it continues to be successful well into the future.

Designate a compost coordinator. A coordinator is responsible for making sure the system runs smoothly and is integrated with other functions of the farm.

Integrate composting into your year-round farm schedule. When you build a new pile, look ahead and estimate when the compost will be ready to use. Aim to build piles in time so that cured compost will be ready for Spring and Fall bed prep and planting.

Teach others. If several core staff members and volunteers know the basics about composting, they can help keep the system running. Composting appeals to the thrifty person in all of us, and it's easy to find people who want to roll up their sleeves and get involved. There are many tasks that staff and volunteers can perform with minimal training, such as collecting and storing feedstocks, and building, monitoring, and turning compost piles, moving compost for curing, and applying compost during bed prep. Getting multiple people involved will ensure the longevity of your composting program. If only one person is involved in composting, the farm risks a setback if that person leaves the farm.

9. Tools and Resources

A. Carbon to Nitrogen Ratio of Common Feedstocks
B. Compost Pile Monitoring Record
C. US Composting Council's Measuring Compost Moisture by Look and Feel
D. Regular Composting and Worm Composting Troubleshooting Guides
E. Composting Resources

A. Carbon to Nitrogen Ratio of Common Feedstocks

Nutrient ratios by dry weight of feedstocks.

	Material	C:N ratio	Descriptor	Notes
Browns	Cardboard & newspaper	560:1	very high carbon	
	Sawdust	442:1	very high carbon	Use sparingly, can clump up and restrict airflow
	Woodchips	250:1	very high carbon	Excellent material, provides good structure
	Rice hulls	120:1	high carbon	
	Corn cobs	98:1	high carbon	
	Straw	80:1	high carbon	Excellent material, provides good structure
	Corn stalks	67:1	high carbon	
	Shrub trimmings	53:1	neutral	Chop into 4" pieces
	Fallen leaves	39:1	neutral	
Greens	Non-legume hay	32:1	neutral	
	Horse manure	30:1	neutral	May contain gravel and require screening
	Coffee grounds	20:1	high nitrogen	
	Cattle manure	19:1	high nitrogen	May contain gravel and require screening
	Vegetable waste	19:1	high nitrogen	
	Legume hay	18:1	high nitrogen	
	Tree trimmings	16:1	high nitrogen	Chop into 4" pieces
	Fruit waste	16:1	high nitrogen	
	Grass clippings	15:1	high nitrogen	
	Alfalfa pellets	15:1	high nitrogen	
	Sheep manure	14:1	high nitrogen	May contain gravel and require screening
	Broiler chicken manure	14:1	high nitrogen	May contain gravel and require screening
	Pig manure	13:1	high nitrogen	May contain gravel and require screening
	Kitchen scraps	10:1	very high nitrogen	
	Seaweed	10:1	very high nitrogen	
	Chicken & turkey manure	6:1 to 14:1	very high nitrogen	May contain gravel and require screening
	Weeds	6:1 to 15:1	very high nitrogen	Don't use invasive weeds or those that have gone-to-seed
	Crab and fish waste	5:1	very high nitrogen	
	Blood meal	3:1	very high nitrogen	

B. Compost Pile Monitoring Record

Pile number/name: _____

Date built: _____

Name of builder: _____

	Feedstock 1	Feedstock 2	Feedstock 3	Feedstock 4	Feedstock 5	Feedstock 6
Feedstock Used						
Volume/Part Feedstock						
C:N Ratio of Feedstock						

Date	Time	Name	Moisture? (good, too wet, too dry)	Temperature? (Fahrenheit)	Other Notes?	Watered? (Yes or No)	Turned? (Yes or No)

Date	Time	Name	Moisture? (good, too wet, too dry)	Temperature? (Fahrenheit)	Odors or pests?	Other Notes?	Turned? (Yes or No)

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Measuring Compost Moisture by Look and Feel

The ideal moisture content for composting is between 40-60%. So, how do you estimate the moisture level in your compost pile? Take a sample of compost in your hand from roughly 18 to 24" into the pile. Make sure there are no sharp objects in the sample. Squeeze tightly.

Moisture Content	Description	Implications
65% or more	Water flows freely out of your hand	Too wet, anaerobic conditions likely.
60-65%	A few drops of water are visible between your fingers.	This is acceptable starting point in the dry season, when you want more moisture in the pile.
55-60%	You don't see any water between your fingers, when you open up your hand a sheen of moisture is clearly visible.	Ideal starting moisture content
50-55%	No sheen is visible and a ball of compost remains in your hand. If you tap the ball gently the ball stays intact	This is a good maintenance moisture content for composting.
45-50%	A ball of compost forms, but breaks apart during tapping.	As a pile moves towards the end of the composting process, let it dry out somewhat. The pile will continue to compost well. As the moisture level is reduced, the compost becomes lighter and easier to screen
40-45%	After squeezing, the compost does not remain in a ball when opening your hand.	This can a good starting point when going into the wet season. The compost pile will be able to absorb some moisture. It is also a good moisture content when entering the curing phase of the compost.
Below 40%	No ball forms and a dry talcum-like feeling remains on your hand after discarding the material	Too low - this level slows down the composting process.

Developed by Will Bakx of Sonoma Compost Company. Laboratory tests of compost samples have proven these moisture ratings to match descriptions. These specific percentages may vary with different materials, however, experience will allow any composter to fine-tune this method to his or her specific product.

D. Regular Composting Troubleshooting Guide

Symptom	Potential Cause	Potential Solution
Pile not composting or reaching hot temperatures	Too dry	Add water until slightly damp. Turn pile.
	Too much brown/high carbon material, not enough green/high nitrogen material	Add fresh green waste, herbivore manure, or fruit and vegetable trimmings. Turn pile.
Pile smells rotten and/or attracts flies	Too wet, anaerobic conditions	Turn pile. Remove lid and expose pile to light in muddy conditions.
	Too much green/high nitrogen material	Add more brown/high carbon materials.
	Green/high nitrogen materials exposed, uncovered by brown/high carbon materials	Bury and mix green materials into pile, add at least a 2 inch layer of brown/high carbon materials on top.
	Non-compostables in pile, such as meat, dairy products, cooked foods, greasy foods, etc.	Remove non-compostable materials and turn.
Rodents in pile	Green/high nitrogen materials exposed, nesting has occurred under pile, bin has holes larger than 1/4 inch, and/or non-compostables in pile	Make sure the bin is rodent-proof with hardware cloth, set traps, remove non-compostables, and turn pile. Rodents are also deterred by hot pile conditions.
Ants colonized pile	Too dry	Add water until slightly damp, turn pile. Water and turn daily for a week.
Pile dries out too fast	Pile is exposed to sun or external heat	Relocate pile to shady spot, cover bin with lid. Materials not chopped enough.

D. Worm Composting Troubleshooting Guide

Symptoms	Potential Cause	Potential Solutions
Worms are dying	Worms ate all the food and bedding	Harvest compost, add fresh bedding and food.
	Too dry	Add water.
	Too wet	Add dry bedding, make sure bin has adequate drainage.
	Too hot	Provide more shade, insulate the bin, remove food from part of the bin.
	Too cold	Insulate the bin, add extra food to part of the bin.
Bins attracts flies and/or smells bad	Food exposed/overfeeding	Add 4-6” layer of bedding and stop feeding for 2-3 weeks.
	Non-compostables present	Remove non-compostables: meat, pet feces, greasy food, etc.
Sowbugs, beetles, and colembola in bin	These are good for your worm compost!	

E. Composting Resources

Websites

- **StopWaste Gardening** – General compost and mulch resources, workshops, and how-to videos: www.stopwaste.org/gardening.
- **StopWaste Worm Compost** – Worm composting information and worm sources in the Bay Area: www.stopwaste.org/worms.
- **StopWaste Compost Bins –** Schematics for building hot-compost and worm compost bins: www.stopwaste.org/compost-bins.
- **Lawn to Garden** – Sheet mulching, weed suppression, and lawn conversion information: www.lawntogarden.org.
- **Compost and Mulch Vendor Marketplace (Lawn to Garden)** – Directory that lists Bay Area sources for bulk recycled compost, mulch, and sheet mulch materials**:** www.lawntogarden.org/marketplace.
- **Alameda County Resource Conservation District** – Technical assistance and grant funding: www.acrcd.org.
- **Carbon Cycle Institute** – Carbon farming research and information: www.carboncycle.org.
- **US Composting Council's Research and Education Foundation** – Compost research and professional development: www.compostfoundation.org.
- **The Local Carbon Network** – Biochar & co-composting research and education, local biochar distribution, carbon drawdown: www.localcarbon.net.
- **Pacific Biochar** – Biochar research, production, and information: www.pacificbiochar.com.

Books

- **The Rodale Book of Composting: Easy Methods for Every Gardener**, Rodale Press.
- **On-Farm Composting Handbook**, Natural Resource, Agricultural, and Engineering Service.
- **The Compost & Climate Connection: A Land Manager's Guide to Organics**, Composting Council Research and Education Foundation.
- **Community-Scale Composting Systems: A Comprehensive Practical Guide for Closing the Food System Loop and Solving our Waste Crisis**, Chelsea Green Publishing, by James McSweeney.
- **The Worm Farmer's Handbook, Mid- to Large-Scale Vermicomposting for Farms, Businesses, Municipalities, Schools, and Institutions**, Chelsea Green Publishing, by Rhonda Sherman.
- **Worms Eat My Garbage: How to Set Up & Maintain a Worm Composting System**, Flower Press, by Mary Applehof.

Field Guides

- **Field Guide to On-Farm Composting**, Natural Resource, Agriculture, and Engineering Service, by Mark Dougherty.
- **Field Guide to Compost Use**, US Composting Council.
- **Tools for Building Healthy Soil**, StopWaste.