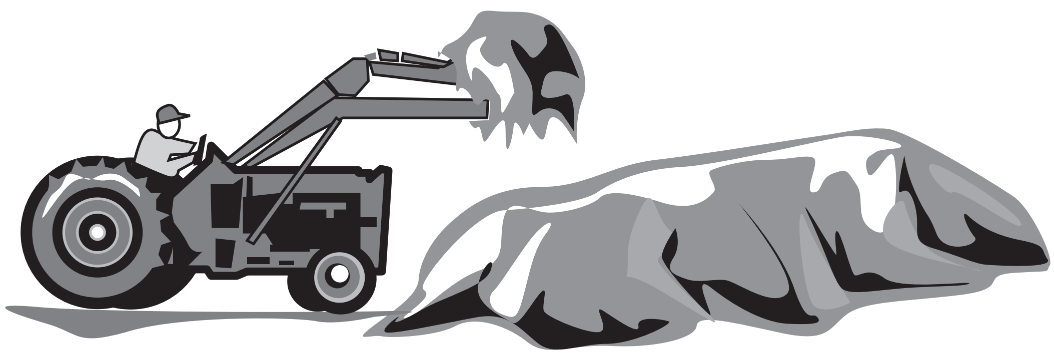
Guide for Community Yard Waste Composting *in Kansas*



KANSAS STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
AND COOPERATIVE EXTENSION SERVICE

Composting is a biological process by which microorganisms convert organic materials into a dark humus-rich soil-like material called compost. It is the same natural process that produces the dark humus layer on the forest floor. Composting differs only in the intentional creation of conditions that result in more rapid decomposition of organic material than what would normally occur in nature.

For centuries composting has been a common practice for disposing of organic residuals while, at the same time, producing a useful product. Modern composting differs only in the application of scientific knowledge and technology to promote more rapid decomposition and better control of the final product in an environmentally sensitive way.

Compost can be valuable in enhancing soil physical and chemical properties. Compost contains small amounts of important plant nutrients and many micronutrients. Addition of compost to soil can improve soil tilth and fertility. Compost is free of objectionable odors and stores and handles well. Properly processed compost is free of most pathogens and weed seeds. Compost has been shown to suppress certain soilborne diseases and can be used as a mulch to reduce weed growth.

What can be composted?

Just about any plant or animal material can be composted. The most common compost ingredients are yard trimmings, manure, and food and food processing wastes. Composting is rapidly expanding in popularity as a method for stabilizing sewage sludge, though it has been a common practice for centuries. Many common components of the waste stream, such as paper, cardboard, and textiles, are composted. In several locations around the country the entire organic part of municipal waste is composted. Composting also is becoming an important way of disposing of poultry and livestock mortalities. More recently, composting has been found to have value in treating and reducing toxicity of some types of industrial waste and chemically contaminated soil.

Yard trimmings, such as grass, leaves, tree and shrub trimmings, and garden waste, make up one of the largest single components of waste buried in landfills—sometimes as much as 15 to 20 percent or more. With increasing concern about local landfill capacity, the cost of landfilling, and the cost of transporting waste to regional landfills, many communities are looking at composting to reduce the waste stream while producing a useful product. Some communities have carried out educational programs that encourage citizens to leave grass clippings on the lawn. Nevertheless, composting is often the most economical alternative for dealing with the total volume of yard trimmings. It helps avoid landfill tipping fees and long-distance transportation costs, provides organic material and mulch that can be used by the community or returned to its citizens, and, sometimes, creates a source of income through the sale of compost.

The size of composting operations can range from simple backyard bins to large community or regional systems. For many communities, the best solution has been to promote backyard composting to reduce the transfer of yard trimmings to landfills. Some have provided free or reduced cost composting bins to local citizens. Extensive educational programs usually accompany these efforts. A few communities have even trained a cadre of master composters to help in training others in the science and art of composting. However, backyard composting is usually not a complete solution. Most communities will find a need for a central site for composting yard trimmings that backyard composting simply cannot handle.

This guide focuses on central-site composting of yard trimmings. However, these basic composting concepts are equally applicable to backyard bins and to composting of a wide range of organic materials.

The composting process

Composting is accomplished by the feeding and digestive processes of a wide range of microorganisms and invertebrates, including fungi, insects, and worms. Bacteria are, perhaps, most important in the composting process. The method of composting is based on the characteristics of different groups of organisms in terms of their requirement for oxygen and the temperature range in which they flourish.

Most composting is done under aerobic conditions by organisms that require oxygen to survive. The primary by-products of aerobic composting, besides compost, are CO_2, water, and heat (Figure 1). Organisms that do not require oxygen (anaerobic) can also break down organic material. However, the process is usually slower, and by-products include methane gas and other vapors, many of which have strong odors. Decaying material also has a tendency to become more acidic under anaerobic conditions. Therefore aerobic composting is usually the preferred method and is the focus of this guide.

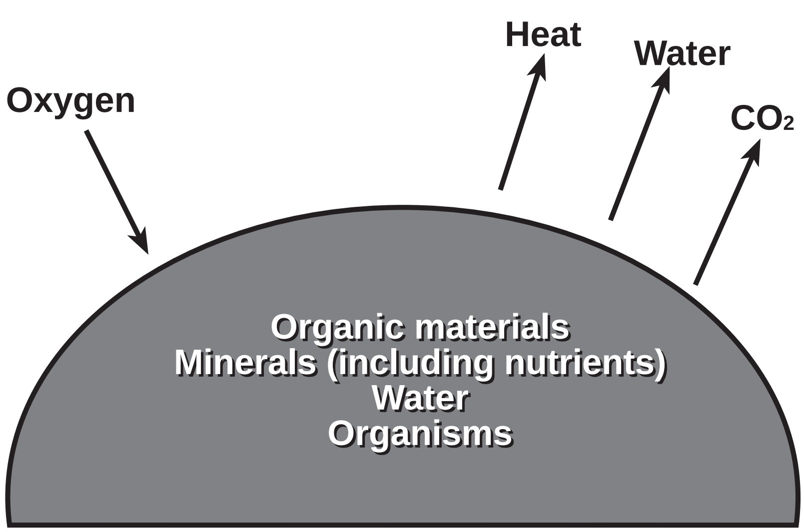


Figure 1. *Aerobic organisms require oxygen. The primary by-products of aerobic composting are compost, heat, water, and carbon dioxide.*

Aerobic organisms necessary for composting are abundant in nature. Adding cultures of organisms to organic materials to promote composting should not be necessary.

Aerobic composting can occur under a wide range of temperature conditions. Initial decomposition is carried out by mesophilic organisms that exist in temperature ranges from 50˚F (10˚C) to 113˚F (45˚C). They break down soluble and easily degraded compounds. As they give off heat, the temperature in the compost increases rapidly.

The mesophilic organisms are replaced by thermophilic organisms that thrive under temperatures between about 113˚F (45˚C) and 150˚F (65˚C). These high temperatures promote the breakdown of proteins, complex carbohydrates, and other organic compounds that provide important nutrients for the microorganisms. Most thermophilic microorganisms involved in composting begin to die off at temperatures above 150˚F (65˚C) and few can survive above about 160˚F (71˚C). If temperatures are allowed to exceed these high levels, rapid decomposition will cease and the pile will return to mesophilic conditions. Therefore, temperature management is an important part of a composting operation. Aeration and mixing are used to keep temperatures from falling too low or rising too high.

As nutrients for the thermophilic organisms are depleted, those organisms become less prevalent and the temperature begins to fall. Mesophilic organisms again take over and complete the composting process in what is called the “curing” phase. Figure 2 shows the various temperature phases over time in a compost pile.

Like humans and animals, organisms involved in composting need the right amounts of water, nutrients, and oxygen to survive. Managed composting means managing these factors to create optimum living conditions for composting organisms.

Water

Microorganisms need water to survive. Composting works best if the composting material is between 40 and 60 percent water. While organic decomposition will occur at higher or lower moisture content, the rate will decrease. If the material is too wet, the pores in the compost pile will fill with water and reduce the flow of oxygen necessary for living microorganisms. When moisture is above 60 percent, the compost approaches saturation and the pile will not heat and anaerobic conditions will prevail. When moisture is so high that it flows freely from the compost pile it may cause dissolved nutrients to leach out, causing potential pollution of ground or surface water. If moisture levels are too low, organism populations will decrease and decomposition will be quite slow. Below 30 percent moisture, microbial activity nearly ceases.

If the material to be composted is initially dry, it will be necessary to add and thoroughly mix additional water or to add material with a high moisture content. Water sprayed on top of a compost pile may run off. Usually, it is necessary to make an indention or trough in the top of the pile where water can be added or to add moisture while the pile is being agitated (Figure 3). It is likely that additional water will need to be added sometime during the composting process. Although water is a by-product of decomposition, the heating of the pile causes moisture to be lost as vapor. Dryness is one of the most common causes of slowed or halted composting during hot summer months. Compost managers often mistake the cooling of a compost pile because of dry conditions as an indication that the composting process is complete.

If composting material is too wet, it may be necessary to add dry “bulking” material to lower the moisture content. Addition of coarse dry material such as wood chips, straw, or leaves, will also increase the pore space to allow oxygen to penetrate the compost pile better. Another way to overcome wet conditions is to agitate the pile to increase pore space.

The most accurate method for measuring the moisture content of compost is to oven-dry a sample (8 hours at 219˚F/104˚C) and dividing the difference between the wet weight and the dry weight by the wet weight. In actual practice the squeeze test will be all that is needed. In this method, if squeezing a handful of material results in the release of only a few drops of water,

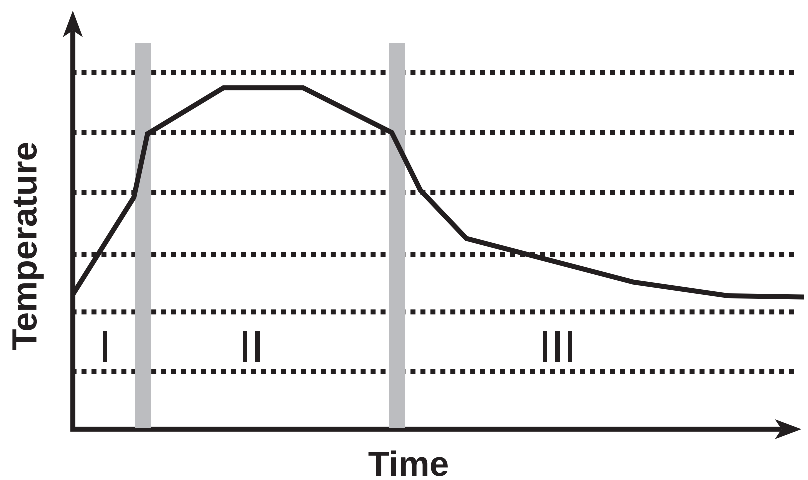


Figure 2. *The first phase (mesophilic) may last only a few days as the compost heats rapidly. The second phase (thermophilic) is where rapid decomposition occurs over a few weeks to a few months. Mesophilic conditions return during the third cooling and curing phase that may take several months.*

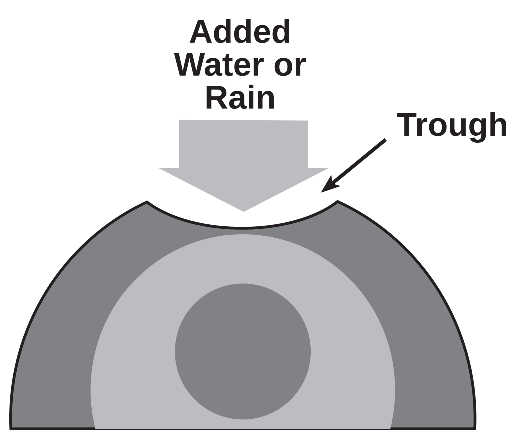


Figure 3. *A trough in the top of pile will allow rain or added water to soak in rather than running off.*

the moisture is just about right. Unless the material feels quite damp, the moisture level is probably too low.

Nutrients

Microorganisms in the composting process must have sufficiently balanced nutrient sources. This is usually described as the carbon:nitrogen ratio (C:N). Microbes rely on carbon in the composting material for their energy source and it is a basic part of their cell structure. The most biodegradable carbon forms, such as sugars and starches provide the most energy. Some less biodegradable carbon forms, such as lignin in wood, are broken down by only a few microbes. And some carbon compounds, such as those in plastics, may not be biodegradable at all. Those easily broken down carbon compounds will be consumed by the organisms and eventually be released to the atmosphere as carbon dioxide. The least biodegradable carbon compounds may remain as a basic part of the remaining humus.

Table 1. *Typical Carbon:Nitrogen Ratios for Selected Materials*

Grass clippings	19:1
Digested sewage sludge	16:1
Food wastes	15:1
Cattle manure	19:1
Laying hen manure	6:1
Tree leaves (dry)	54:1
Tree bark (hardwoods)	223:1
Wood chips/sawdust	300:1 - 700:1
Waste paper from refuse	170:1
Corrugated cardboard	563:1
Hay (legume)	16:1
Hay (grass)	32:1
Straw (wheat)	127:1
Corn silage	40:1
Slaughterhouse waste	4:1
Paunch manure	25:1

Adapted from: On-Farm Composting Handbook, 1992, and Cornell Composting: Operator's Fact Sheets, 1992, and other sources.

Though microbes require a broad range of other nutrients, nitrogen is the most important because it may be lacking in many organic materials and because it is necessary for the formation of proteins, nucleic acids, and amino acids that make up the bodies of microbes. The amount of nitrogen will control, to a great extent, how many microbes will be present.

The C:N ratio is one of the most important considerations in successful composting. Experience has shown that the ideal C:N ratio is about 30 (30 parts carbon to one part nitrogen). Ratios wider or narrower than that range will likely cause material to decompose much more slowly. C:N ratios of composting organic materials vary widely. Typical C:N ratios for waste products are 15 to 20 for manure, 20 to 80 for yard waste (depending on the mix of grass and leaves), and 400 to 700 for woodchips or sawdust. To obtain the optimum C:N ratio, mixing several materials is often necessary. Table 1 lists the C:N ratio of various organic materials.

If the C:N ratio is too wide, there may not be sufficient nitrogen for microbial development, resulting in slowed decomposition of carbon compounds. The best solution is usually to add additional material with a narrower C:N ratio. In yard waste composting, fresh lawn clippings are a good source of high-nitrogen material. It also is considered permissible to carefully add livestock manure as a nitrogen source. Complete mixing will be important and the manager should be aware that addition of manure could temporarily increase odor problems. Some managers add chemical nitrogen fertilizer to improve the C:N ratio. However, is usually not wise to correct the C:N ratio with a single application, but rather with several small, well-mixed applications. If too much concentrated fertilizer nitrogen is added, it may exceed the capacity of the organisms and ammonia compounds may form that may increase undesirable odors and be lost to the atmosphere as ammonia gas. Worse still, nitrogen could be leached from the pile as nitrate, causing a potential groundwater contamination problem.

It is particularly important that the initial C:N ratio not be too narrow. As composting proceeds, the C:N ratio gets even more narrow with carbon released as carbon dioxide. Organisms populations will decrease due to insufficient energy sources. Nitrogen that accumulates may convert to ammonia or nitrous oxide compounds and be released to the atmosphere, often resulting in strong odors.

Oxygen

Oxygen is critical to aerobic composting. If oxygen is not present, anaerobic organisms take over. Composting slows and strong odors are likely, especially a rotten egg odor from the release of hydrogen sulfide gas. As aerobic microorganisms oxidize carbon, oxygen is used and carbon dioxide is formed. Therefore, the oxygen supply must be continuously replenished. At least 5 percent oxygen is needed for aerobic organisms to survive, though 10 percent would be nearer to optimum.

Some composting systems use mechanisms to blow or draw air into the pile. Most systems rely on diffusion of oxygen through the composting material by convection. The heating of the pile creates a chimney effect where the hot oxygen-depleted air moves out of the top of the compost pile while cool oxygen rich air is drawn in through the sides (Figure 4). Diffusion of oxygen is dependent on adequate pore space. High moisture content, small particle size, and compaction all contribute to reduced pore space and poor oxygen flow. Aeration of the compost pile is accomplished by careful construction of the pile and by mixing to “fluff” the material to increase pore space to optimize oxygen diffusion.

Temperature

Besides the requirements for air, food, and water, temperature also affects the growth of microorganisms and the rate of decomposition. Heat is a very important part of the composting process. Low temperatures result in the growth of mesophilic organisms that decompose organic material quite slowly. However, under thermophilic conditions, the temperature in the middle of an active compost pile can sometimes reach 160˚F (71˚C) or more, killing the composting organisms (Figure 5). Under most conditions, the optimum composting temperature should be between about 120˚F (49˚C) and 140˚F (60˚C). Temperature is usually controlled by mixing or “turning” of the pile when temperatures exceed or fall below that range.

Higher temperatures do serve an important and necessary purpose. Most human and plant pathogens are destroyed at temperatures above 131˚F (55˚C). Most weed seeds are killed at a temperature of 145˚F (63˚C). However to be certain of destroying all pathogens and weed seeds, the compost pile must be mixed several time and allowed to reheat to the critical temperature to expose all of the organic material to the high temperatures. In windrow systems, it is recommended that the pile be allowed to heat to at least 131˚F (55˚C) and remain at that temperature for 3 days. That process should be repeated through five turnings with the temperature allowed

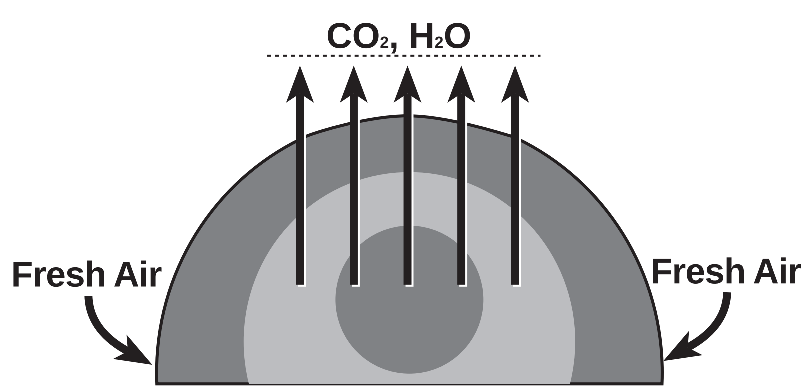


Figure 4. *Warm CO_2 and H_2O-rich air is removed and fresh, oxygen-rich air brought in by convection.*

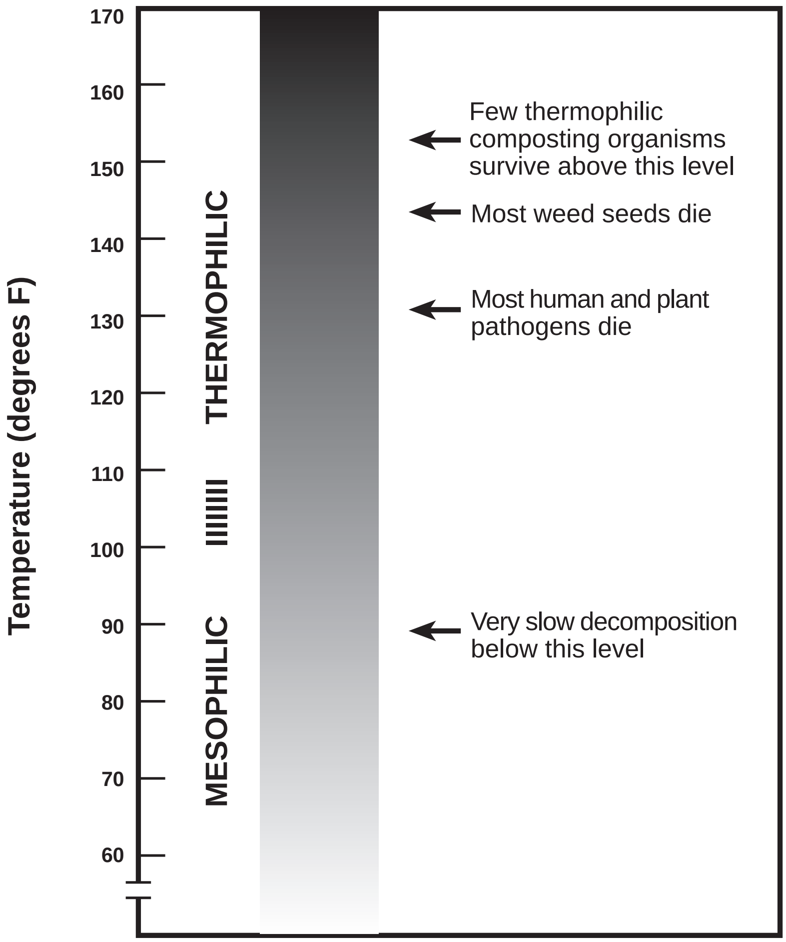


Figure 5. *Summary of expected windrow temperature conditions.*

to rise to 145˚F (63˚C) at least once. After that sequence, the temperature can be maintained at a somewhat lower level.

Other considerations

Acidity (pH). The pH of most finished compost will be in the desirable 6.5 to 8.0 range. However, during the early stages of composting, organic acids are formed causing a slightly acid condition. This slight acidity is actually beneficial to some composting organisms, especially some fungi. However, if anaerobic conditions are allowed to develop during composting, the organic acids may accumulate. This can usually be remedied by aeration of the pile. Adding lime to raise the pH is usually not wise. The sudden change may create locally alkaline conditions that may cause loss of ammonium nitrogen to the atmosphere. This will result in odors and loss of nitrogen from the compost.

Micronutrients. Composting microorganisms require a wide variety of micronutrients. However, those micronutrients will nearly always be present in sufficient amounts in the composting material and will not need to be added to the mix.

Particle size. Particle size affects porosity, or open spaces in the composting material. Very fine material will have smaller pore spaces that can become filled with water. However, large particles provide less surface area for microbial action. While there is no perfect answer for all materials, having a range of particles from ⅛ inch to ½ inch is usually best. However, in practice, if moisture level and compaction are not allowed to become excessive, adequate aeration will allow composting of either finer or coarser material.

Particle size also affects the speed of composting. Microorganism activity is greatest at the surface of the particle. Small particles provide more surface area in a given mass of material. Particle size distribution can be improved by grinding the material, though this can add considerable expense for small operations. The manner in which the wood is chipped can be important. Smooth surfaced chips provide less surface area for microorganism activity than more irregular shredded material.

Particle size also has an impact when adding material to adjust the C:N ratio. Wood chips are frequently used to raise the carbon content. However, only the surface of the wood chip is actually available to the organisms. Therefore, an excessive amount of wood chips may need to be added to meet immediate carbon needs. This often results in undecomposed wood particles in the finished compost. The resulting compost is not only unattractive, it may also have a temporary negative impact on soil fertility when the compost is used as a soil amendment. The microbes in the soil will rob the soil of nitrogen as they work to decompose the woody material. To remove large undecomposed material many compost managers screen the compost and put the larger particles back through the composting process. Only that part of the compost passing through a ⅜ inch to ½ inch screen is then used as a soil conditioner. Again, some composters may grind the material to achieve the optimum size. However, while it may improve the appearance of the compost, it may actually be an inferior product containing fine undecomposed material in the compost.

Table 2 shows ranges for C:N ratio, moisture, temperature, and oxygen in composting.

Table 2. *Composting conditions*

	Reasonable Range*	Optimal
Oxygen	>5%	>10%
Moisture	40 - 65%	40 - 60%
Carbon:Nitrogen Ratio	20:1 - 40:1	30:1
Temperature	90 - 145°F	120 - 140°F

*Decomposition will occur outside these ranges—just more slowly with possible side effects, such as odor.

Composting methods

There are several methods used in aerobic composting. They vary, primarily, in the method of air supply, temperature control, and the method of mixing of the organic mass. Higher levels of technology tend to have a greater capital cost but can produce a larger amount of higher quality compost in a shorter time—often with less labor.

Passive composting

Passive composting means making a pile of material and letting it set until it decomposes. It operates under the assumption that if something is left long enough it will decay and is sometimes referred to as a "rot pile." It will usually take a long time—perhaps years—to produce a stable compost product. The method is likely to produce odors, because of anaerobic conditions, especially with high moisture material. The finished product will probably contain a mixture of decomposed and undecomposed material. Some would argue that this is not really composting at all since it is not a controlled process.

Windrow composting

In this, the most common method of composting, organic material is formed into windrows. These windrows are long piles with a triangular cross section that are turned or stirred to provide aeration.

Frequent turning of the material provides aeration, mixes the material, helps control temperature, and redistributes moisture. Turning is usually accomplished by using some type of front end loader or specially designed windrow turning machines. Windrow turners can be quite expensive and are usually not affordable for small composting operations. Front end loaders (Figure 6) can do a good job but will be more labor intensive and may require more room to maneuver.

With proper management, windrow composting can produce a high quality product. However, too often the windrows are not turned in a timely manner. Windrow operations also require more land area than some more intensive methods because of the length of time required for the composting and curing process and space for maneuvering equipment. Windrow composting process will take from several months to more than a year to reach completion.

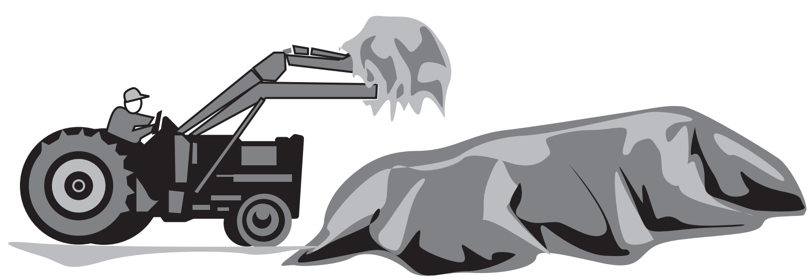


Figure 6. *A front-end loader can do a good job of building and turning windrows, but can be labor intensive for large operations.*

Most community or on-farm composting operations will rely on the windrow method because of its relatively low cost and simplicity. However, there are other methods in wide use.

Aerated static pile

In the aerated static pile method, aeration is accomplished by mechanically pushing or pulling air through the pile rather than by mixing or turning. The piles are usually built over a network of perforated pipe attached to a blower (Figure 7). The material is not disturbed until the composting process is nearly complete. Then the material may be placed into windrows and turned or into static curing piles for final decomposition and curing.

The aerated static pile method can offer advantages in odor control. By pulling fresh air into the pile, the "stale" air pulled from the pile can be run through some type of biofilter that minimizes odors. A biofilter is usually constructed of a mixture of wood chips and finished compost. Aerated static pile composting is often employed when composting odorous, fine, or high-moisture material, such as sewage sludge biosolids.

Aerated static pile composting requires a higher level of technical management than windrow composting and, usually, higher initial capital costs. However, it requires less land area and offers greater opportunity for odor control. Composting can take from 6 to 12 weeks, but may take longer.

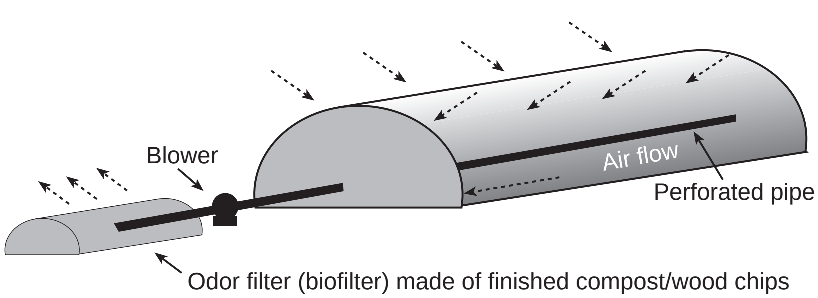


Figure 7. *Simplified drawing of aerated static pile showing how air is drawn through the pile. Odor is controlled by blowing air through a biofilter.*

In-vessel composting

In this form of composting, the organic material is placed in some type of enclosed or partially enclosed structure, such as a bin, vat, or rotating drum. The bin type of structure is usually in an enclosed or roofed building. Aeration is provided by forced air or, mechanically, by a moving agitator. Enclosed bins are usually aerated by forced air. The rotating motion, along with forced air, provides aeration in the rotating drum type of facility. The enclosed bins or drums can permit a high level of control of temperature, moisture, air flow, and odor. Because of the constant mixing, in-vessel composting can produce a very uniform and high quality product. While it can be quite expensive and require a great deal of technical management, the process can handle large quantities of material in a relatively short time with a low land area requirement. Compost can be ready for curing in as little as a week or two.

Windrow composting basics

Material to be composted can be dumped directly into a windrow or placed in a staging area. Use of a staging area permits sorting contaminants from the material and allows materials of varying C:N ratio to be mixed in the proper proportion. The windrow is usually built and shaped using a front end loader. With yard waste, an equal amount of grass trimmings and leaves will usually offer about the right C:N ratio and moisture range. After it is mixed, the material is then placed on a firm well drained surface that will permit turning activity under a range of weather conditions. If moisture is low, it may be necessary to add water to the mix as it is placed in the windrow.

The width of the triangular cross section windrow is usually about twice the height, typically ranging from 3 to 10 feet high and 8 to 20 feet wide at the base (Figure 8). The height and width will vary with the density and moisture content of the material and the kind of equipment available to turn and aerate the material. A windrow can be any length that can be comfortably handled given the space and equipment available.

Dense, wet material is usually placed in lower windrows to reduce compaction. If a windrow is too high, aerobic zones may occur near the lower portion of the pile, releasing objectionable odors when the windrow is turned. However small windrows may lose heat or never reach temperatures high enough for rapid composting or to control pathogens and weed seeds, particularly in cold weather.

Turning the windrow

For maximum speed of composting, windrows may be turned as frequently as weekly, or more often if high temperature goals are reached. However, most small operations perform turning operations less frequently. Usually the temperature of the middle of the pile is an indicator of time to turn the pile. The pile is turned after pathogen and weed seed destruction temperatures have been reached, but before reaching temperatures that impede composting.

While specialized mechanical windrow turning machinery can help provide ideal composting conditions, a front end loader also can provide a satisfactory and cost-effective means of turning or agitating the material for operations processing less than 3,000 tons per year. Turning with a loader is accomplished by approaching the pile from the side and using the bucket to roll the side of the pile over the top, thus moving the material from the center of the pile to the outside (Figure 9). Several turnings will be necessary to make certain that all of the material has been exposed to optimum composting conditions. It also may be necessary to add water as the pile is turned, making certain to fully blend the water in the pile to avoid saturated pockets. Depending on the size of the equipment, windrows turned with a loader may have to be 20 feet or more apart to allow room to maneuver. As composting proceeds, the volume of the windrow will decrease.

Combining two adjacent windrows that are at about the same stage of decomposition is often possible.

Mechanical windrow machines, while expensive, can reduce labor costs and provide excellent mixing. They may be either self-propelled or pulled behind a tractor. Some straddle the windrow, completing the mixing in a single pass. Others mix only about half the windrow and require a pass on each side. Some machines are equipped to add water during the turning process. Mixing is accomplished by flailing blades, augers, or a conveyer face that lifts and dumps the material. Flailing blades offer the advantage of further breaking up coarse material. However, if material is already fine, the others treat the material more gently to not excessively reduce pore space. Mechanical

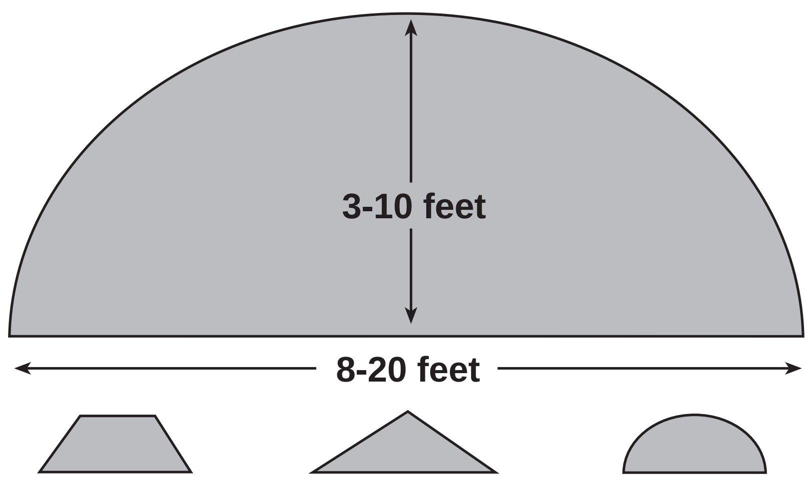


Figure 8. *Typical compost windrow cross sections. Size and shape will depend on material and equipment.*

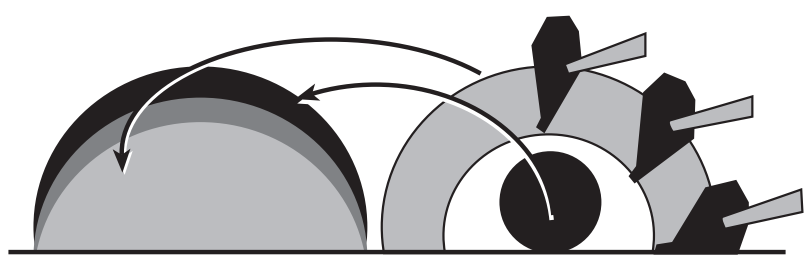


Figure 9. *Turning with a front-end loader is accomplished by successively rolling the pile over the top so that the upper, cool material is turned to the bottom. Allow the material to fall gently to promote mixing and aeration.*

turners usually require less total composting area than front an end loader because windrows can be placed closer together.

Monitoring and finishing the composting process

Ongoing monitoring of the composting process is important to prepare quality compost without producing objectionable by-products. In addition, steps can be taken to prepare the compost for desired uses.

Monitoring

Conditions in a compost pile can change quite rapidly. Regular monitoring will provide evidence of the progress of the composting process and indicate when actions need to be taken.

Moisture. The optimum 50 to 60 percent moisture should be maintained throughout the active composting process. The squeeze test should be performed regularly, particularly when the windrows are turned. Water should be added and thoroughly mixed as needed to maintain optimum condition. If rainfall has resulted in too much moisture, it may be necessary to turn the pile to provide aeration.

Temperature. Most compost managers use temperature as a primary management indicator. It can help determine when it is time to turn the pile and when rapid composting is complete. Temperature of the internal part of the windrow should be checked regularly in multiple locations. This can be done with long-stemmed metal thermometer designed for use in composting. A thermometer with a three foot stainless steel stem can be purchased for under $100 (Figure 10). During the active composting period, high temperatures indicate that it is time to turn the windrow. Failure to reheat after turning can be an indicator that moisture levels are too low or too high. Low temperatures also could occur if the initial C:N ratio was too wide and all of the nitrogen has been consumed. In this case, undecomposed material will likely be present. If moisture is within the proper range, and decomposition appears to be complete, failure of the windrow to reheat after turning is a good indicator that active composting is complete.

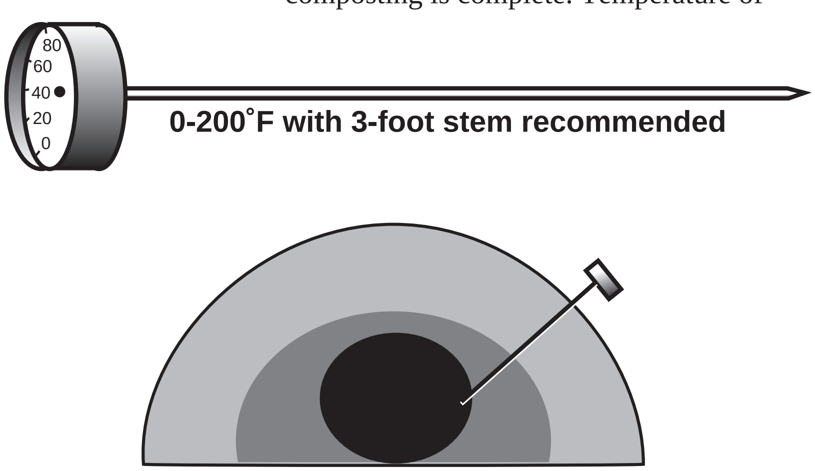


__Figure 10.__ A stainless steel, long-stemmed dial thermometer is inserted into the center of the pile at several locations to measure temperature.

Odor. Any time objectionable strong odors are observed, it is likely that anaerobic conditions are present in the compost pile. That can be caused by moisture levels that are too high in part or all of the pile. It also can be caused by excessive compaction within the pile. If strong odors are present, the pile should be turned. However, the turning process will initially release even more odor. The best practice is to try to avoid conditions that may produce odor throughout the composting process.

Oxygen. Some advanced operations regularly test for oxygen (or carbon dioxide) using fairly sophisticated testing equipment. Presence of adequate levels of oxygen indicates that aeration is adequate. High levels of carbon dioxide indicate that microorganisms are still quite active. However, because of costs associated with such tests and difficulty in interpreting results, relative few community composting operations include them in the monitoring process. In most cases, aeration based on temperature monitoring will provide adequate oxygen.

The look and feel test. The final test of composting is the look and feel of the material. It should be a dark brown to black spongy material made up primarily of fibrous humus material. It should have an earthy smell.

Curing

At the end of the active composting period, assuming optimum conditions have been maintained, most easily degradable organic material has been decomposed. The remaining organic material decomposes much more slowly, even under ideal conditions. This is the beginning of what is usually called a curing phase. The compost may be left in the windrows or moved to a larger pile where it is allowed to further decompose very slowly over a period of weeks or months, depending on the desired final quality desired. During this phase, little additional heat should be generated and minimal turning is needed. During curing, the compost becomes biologically stable and the pile will gradually cool to near air temperature. Moisture content will gradually decrease.

Screening

Depending on the expected use of the compost, many operators screen the compost to remove large particles that have not completely degraded. While mechanical screening equipment can be quite expensive, screening may be necessary to meet some use requirements. Compost that is to used primarily as a mulch usually will not be screened. However, compost that is to be bagged or used for potting mixes will usually be screened to ½ inch or less in size. Oversized material is often added back to a compost pile for further decomposition.

Site considerations

Site selection and design is critical to the successful composting operation. Major siting considerations include:

- Adequate land area for the whole composting operation.
- Suitable topography and soil characteristics.
- Location that is convenient for users and minimizes hauling distances.
- An adequate buffer between composting activities and other development.

Land area. There is no generally agreed upon formula for land area requirements. Sufficient land area should be available to provide, not only space for compost windrows, but also space for maneuvering equipment, access by large and small vehicles, staging operations, compost curing, and finished compost storage. Most of the area will be used for windrows. Space needs will have to be calculated based the planned width and height of windrows and an estimate of expected volume of material in windrows at any one time. By knowing windrow volume per linear foot, the total length necessary can be calculated. Space requirements between windrows will need to be taken into consideration, with up to 20 feet needed for front end loader turning. If material is removed from windrows and placed in a separate pile for curing, that area may require about 20 percent as much space as is allocated to the windrow operation. General access, staging, and structures may require about that same amount of space. Additional space will likely be needed for vegetative buffers, terraces and levees, and leachate storage, depending upon site design. In addition, ownership or regulatory control of surrounding areas may be important to prevent development of activities that may be in conflict with a composting operation.

Soil and topographic characteristics. Composting sites should provide adequate all-weather access with a surface that will withstand vehicular traffic while preventing contamination of surface or groundwater. While composting sites should not be steeply sloping, there should be enough slope to prevent ponding of water. A minimum 1 percent slope should be maintained and a 2 to 4 percent slope is better. Steeper slopes can result in site erosion.

Soil conditions on the site are important. Areas to be avoided are those subject to flooding, having poor internal soil drainage, or with a water table near the surface. A paved surface will provide a good surface for equipment and vehicle traffic and will prevent infiltration of leachate from the compost. However, for yard waste composting, paving usually is not necessary if the soil surface is firm, but absorbent enough to prevent ponding. Soil that is too sandy may allow leachate to move rapidly into the groundwater. Heavy equipment and vehicle can cause ruts in the surface when to soil is wet. Limit activity during wet periods and fill damaged areas as soon as possible. Soil survey reports provide information about the soils of the area. USDA Natural Resources Conservation Service soil scientists can help identify soil conditions appropriate for a composting site.

Leachate is produced by water passing through the composting material. It may be absorbed by the soil or be carried from the site as runoff. Runoff is caused by precipitation falling on the site in excess of what is absorbed by the soil. In yard waste composting, the most common potential contaminant is nitrogen released when narrow C:N ratio material is composted. Excess nitrogen, in the form of nitrate, can move rapidly through the soil into the groundwater. Monitoring C:N ratio is important in reducing nitrogen in the leachate.

The most important step in reducing runoff is to minimize the amount of water that will move from the site. While maintaining adequate moisture in the compost windrows is important, watering should not cause free water to drain from the piles. Berms or other structures may be necessary to prevent any precipitation water from moving onto the site. By doing so, the only runoff will be from precipitation falling directly on the site. The composting area should be no larger than is needed in order to limit the area that contributes to runoff.

Runoff water should not be allowed to move into bodies of water. It is recommended that yard waste composting sites be located at least 200 feet from streams and other bodies of water and drinking water wells. Some operations include berms or channels to guide runoff into a "holding pond." That runoff can be used as a water source for windrows. Grassed infiltration strips also can be effective in reducing site runoff.

Location. The compost site must be located so that it is convenient to users. It should be near the community or communities where the yard waste is generated to minimize hauling distance. A central site is especially important to communities relying on drop-off collection of yard waste. It should be on an all-weather road that can withstand the additional traffic load. Often the best location is adjacent to sites where people are already accustomed to taking waste. That might include near recycling centers, on the buffer area of a landfill, or adjacent to a transfer station. Composting sites should not be located in residential areas. Public compost sites are often located on existing public land. However, FAA regulations should be checked before locating a compost site adjacent to an airport.

The compost site also should have ready access to a water supply sufficient to provide water needed to optimize composting moisture levels. Ten gallons or more of water will have to be added each time it is necessary to raise the moisture content of each cubic yard of compost from 30 percent to 40 percent moisture. Access to a water supply for fighting fires is recommended. Electrical service also may be useful in many cases.

Buffer zones. Buffer areas should be provided to separate composting activities from other, possibly conflicting, land uses. Typical concerns include potential odor, traffic, dust, and machinery noise. The site should include a buffer area that separates the actual composting activity from adjacent property that is at least 100 feet in width. The site should be at least 500 feet from residences, schools, and medical facilities. A 1,000 foot distance would be even better. Trees and shrubs can help to provide a visual and noise screen. Fences are recommended to reduce blowing of material off site and to control unwanted access. Site location and design should take into account the direction of prevailing wind and expected traffic patterns.

The best defense against conflicts is to use good management practices. Catch potential problems early and take appropriate action.

Site design. After an appropriate site has been located, it must designed to meet the needs of the operation. In addition to access roads, onsite traffic areas, and buffer zones, and water management facilities, areas must be set aside for receiving and preprocessing of materials, composting, and postcomposting activities.

A separate receiving area provides space for delivery and temporary storage of yard waste, space for mixing and, perhaps, grinding or screening of material, depending on the individual operation. It also provides an area for removal of undesirable material before placement into the windrow. A few larger operations may include scales for weighing incoming and outgoing material. Many small composting operations allow dropped off material to be placed directly into the windrow.

The processing area is the heart of the operation. Windrows are generally placed so they run up and down the slope to allow runoff to move between piles rather than through them. Windrows must be placed to allow sufficient space for machinery and traffic movement. The pad should be sized to meet the maximum expected volume of yard waste. The processing area should also include space for longer term curing of compost.

A postprocessing area provides space for additional processing and storage of finished compost. The finished compost area should have easy access by users of the compost. Space also should be allowed, if needed, for final grinding, screening, or blending of compost. Facilities producing compost for

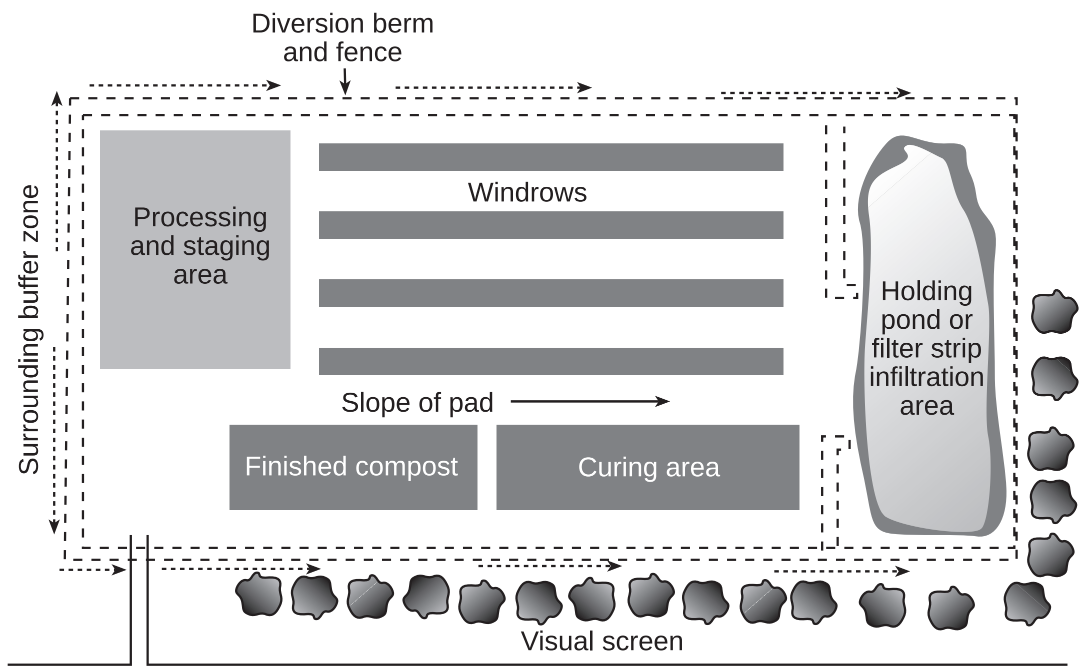


Figure 11. *Example of yard waste composting site layout. (Arrows show direction of water flow.)*

the retail market also may need space for bagging equipment. Figure 11 shows an example of a compost site layout.

Permits and regulations. Operators of community yard waste composting sites must obtain a permit from the Kansas Department of Health and Environment, Bureau of Waste Management. For permitting purposes, yard waste means leaves, grass clippings, garden debris, and small or chipped branches and includes plastic bags used to contain these items. A solid waste composting permit will be needed if other waste materials are included in the compost mix.

Development of a yard waste composting site also may be affected by local regulations, such as zoning. Check with appropriate city or county government offices to find out if there are regulations that will need to be addressed.

Environmental and safety considerations

The goal of a every composting operation should be to safely produce a high quality product without harming the environment. Fortunately, yard waste is a relatively clean product that introduces few hazardous substances into the composting process.

Chemical contaminants. Operators should always be on the lookout for any sources of contamination such as chemical and petroleum containers. They may be an indication that substances may have been disposed of in the yard waste. Public education is a key to limiting such contamination.

There has been some concern about contamination from lawn pesticides. Research studies have rarely found significant levels of such chemicals in finished compost. In most cases, pesticides have undergone considerable degradation before the yard trimmings reach the compost pile. They undergo further degradation during the composting process. One reason for mixing during the composting process is to further dilute any possible concentrations of any chemical residues. Again, public education will be important in discouraging mowing and removing lawn clippings immediately after treatment.

Air quality. After odor, the greatest air quality concern in composting is dust. Significant amounts of airborne particles can fill the air when compost is agitated. While it can create a nuisance, most of the dust does not move a great distance except on windy days. Adequate buffer areas and avoidance of agitation on windy days should limit the problem.

Aspergillus fumigatus is a fungus naturally occurring in decaying organic matter. Its spores can cause health problems in some individuals susceptible to respiratory problems or with impaired immune systems. While instances of problems are relatively rare, health screening is important in hiring workers for compost operations. It is wise for all workers to wear at least basic respirators when compost is being agitated and any time there is considerable dust in the air. In addition, compost facilities should not be placed near medical facilities.

Safety and security. The most obvious safety hazards at composting sites are heavy equipment and vehicular traffic. All employees should be trained in the operation of any equipment and rules should be developed relating to operation of equipment when other people and vehicles are present. Vehicular traffic patterns should be established and carefully marked, particularly in drop off operations. Temporary and permanent fences and barriers can keep foot traffic away from vehicles and equipment.

Fire protection. Though relatively rare, fire is an ever-present potential hazard in composting operations. Fire may be the result of careless smoking, sparks from machinery, hot vehicle exhausts, internal combustion, or even lightening. Good management and housekeeping can reduce most fire hazards. Smoking should not be permitted at compost sites. Keep vehicles away from quantities of dry material. Do not allow large quantities of dry material to accumulate. Mow buffer areas and keep vegetation green.

Spontaneous combustion can occur when a compost pile heat rises very rapidly while some dry material, such as wood chips are present in the center of the pile. Spontaneous combustion fires often are not visible and may envelop large areas of a compost pile before the fire and smoke becomes visible. Internal compost pile fires can be quite difficult to contain and extinguish. Water does not penetrate the compost pile readily and may actually float burning embers to other areas. Usually the pile must be opened and gradually spread while applying water slowly. Sometimes the best approach is to isolate the fire and allow it to burn itself out. Internal combustion fire hazards can be reduced by monitoring temperatures and not allowing the height of the piles to become too great. Piles should be isolated from other piles to better contain any fire that does start.

It is wise to have a contingency plan in place with the local fire department. The plan should include access routes, water supply, special equipment needs, and fire fighting methods.

Using and marketing compost

Composts are used for a wide variety of mulching and soil conditioning activities in landscaping, horticulture, agriculture, land reclamation, and conservation. Usually only the highest quality compost is used for horticultural purposes, particularly in potting mixes and in bagged compost sold at retail. However, even relatively low quality compost finds uses in land reclamation and soil conservation activities where large amounts of organic residue is needed.

Compost can provide small amounts of important plant nutrients and micronutrients and improve nutrient exchange between soil and plants. Because nutrients in compost are in an organic form, they may not be as readily available to plants as chemical fertilizer nutrients. This is particularly true of nitrogen. Over time, soil microorganisms will mineralize the organic nitrogen to the mineral nitrogen (nitrate) that can be used by plants, becoming, in effect, a slow release nutrient source.

However, compost is a rather dilute plant nutrient source, usually containing only about 1 to 2 percent nitrogen. Several tons per acre will have to be applied to provide the nitrogen needs of most agricultural and horticultural crops. At those levels, it is likely that much more phosphorus will be applied than what can be used by plants. That can result in high levels of phosphorus in runoff water.

Immature compost containing material that has not been completely degraded may actually have a temporary negative impact on plant growth. Undegraded organic material is usually high in carbon. Soil microorganisms feeding on that material will use existing soil nitrogen for cell growth. That nitrogen will not be available to plants until the degradation process is complete and the tied up nitrogen is again mineralized. Additional chemical nitrogen fertilizer may have to be added to meet immediate plant needs.

To protect consumers, Kansas statutes require that any material marketed as a fertilizer or soil amendment meet stringent labeling requirements with guaranteed nutrient content. Therefore, unless it has met those requirements, compost should not be marketed as a fertilizer, nor should fertility claims be made.

Compost is at its best as a soil conditioner. It can improve water-holding capacity of sandy soils and improve aeration and tilth in clayey soils. Even compost with large particles is useful as a mulch that can help conserve soil moisture, lower soil temperature, and reduce erosion. While there is evidence that mature, high-quality compost may inhibit some soilborne plant diseases, immature compost may have just the opposite effect on some plants.

Compost is usually marketed in several ways. Many public compost sites simply give part or all of the finished product away to citizens of the community. It is a way of rewarding those who bring yard waste to the composting site. Many communities use the compost on public areas, rather than purchasing mulch and soil amendment material.

Some compost operations sell the finished product on site, either bulk or bagged. Bagging may improve the marketability of compost but adds considerable expense. Others sell the bulk compost to others who sell it at retail or use it as a part of their own business, such as in landscaping. Selling compost usually requires the production of a high quality, consistent product.

There are no universally accepted standards for compost quality. From a consumer's viewpoint, characteristics of good compost to be used as a soil amendment might include the following physical characteristics:

- has a homogeneous dark brown or black color
- has a humus-like earthy smell with no objectionable odors
- is fairly fine texture with no particles larger than about one-half inch.
- is a stable product that stores well and does not get hot or produce odors when wetted
- is free of weed seeds, pathogens, and chemical contaminants
- is free of visible contaminants
- has a pH between 6.0 and 7.8

A closing note

Composting can and will occur under a wide range of conditions and technology. The intensity of management can affect the speed of composting, quality of the final product, and impact on the environment. Inability to operate at the highest levels of technology should not deter small operations from getting started. Most can start with a low level of management and capital cost, adding resources as needed.

The key to composting success is knowing the product and product quality you want to produce and designing a process that will give you that product in an environmentally safe manner.

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William M. Eberle
Extension Specialist, Land Resources
Department of Agronomy
K-State Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

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