

# Compost: Production, Quality, and Use in Commercial Agriculture

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## Introduction

Compost is a soil amendment produced through the metabolism of an organic substrate—a surface on which organisms grow—by aerobic (oxygen-requiring) microbes under controlled conditions. Composting is an ancient agricultural technology going back to biblical times that still has important applications in modern agriculture. Recent years have seen a resurgence of interest in compost for modern cropping systems.

In organic cropping systems, compost provides a primary source of nutrients for the crop. In conventional cropping systems, compost provides a supplementary nitrogen source that complements fertilizer nitrogen to provide a more sustainable farming system.

Compost enables dairymen and livestock owners to reduce the volume of manure leaving their operation and provides a source of nutrients and organic matter for surrounding farms.

Among many misconceptions about compost are what it is, how it is made, and what it can and can't do for the soil and a cropping system. This publication provides a basic overview, explaining the composting process. But first, find more about advantages of composting and benefits of compost application.

For more advanced questions, the author teaches thirty hours of Master Composting classes and offers field demonstrations. Or see additional references at the end.

## Benefits of composting

Compost use in field crops should be part of any long-term crop management plan. Composting also helps dairies manage manure, it has agronomic benefits, it controls plant diseases, and adds nutrients to the soil.

### Manure management

The livestock industry produces large quantities of manure that must be disposed of in a way that prevents contamination of water resources. Composting is an efficient way to deal with manure because it reduces manure volume by 30% to 50% and decreases fuel use and labor requirements. There is a reduction in the number of trips and labor needed for spreading it, even though some additional fuel and labor are needed for the composting process. Composting also greatly reduces odor and fly problems associated with manure.

For the dairyman, a practical aspect of composting is that it allows for the conservation of nitrogen in manure being collected over winter months when the soil is frozen and manure cannot be incorporated. Microorganisms in the compost pile take up nutrients and hold them in their bodies, which prevents leaching (Demmel, 1980; Alleman, 1982).

### Agronomic benefits

Composting converts the substrate into an organic soil amendment rich in soil-building

humic substances. Humic substances bind soil particles to create soil aggregates responsible for good soil structure. Good soil structure modifies the physical properties of soil to create an environment conducive to crop growth and development.

Water movement, heat transfer, aeration, and porosity are all strongly affected by the type and degree of soil aggregation (Brady, 2005). The effects of added organic matter to the soil structure account for observed increases in infiltration rate, water holding capacity, and better soil tilth following composting. Some growers report that fields are much easier to work after compost applications have been made for several years (Demmel, 1980; Alleman, 1982).

While the composting process loses 50% of carbon from the original substrate, mineralizable nutrients in the substrate convert to an organic form that provides a slow release of fertilizer to the crop. This process is complex, with a portion of the compost being mineralized quickly, and a more resistant portion mineralized over the long-term, possibly over a number of years. The situation is beneficial in that it provides a storehouse of nutrients and protects nutrients from leaching loss.

The process of compost mineralization is not well understood, and more research is needed to match nutrient release from this reserve to a crop's nutrient demands. The process is temperature and moisture dependant. In irrigated soils where soil temperatures range between 75°F and 85°F, the release of nutrients will be quicker than where soil temperatures are higher or lower than this range.

In an organic system, compost can also be a primary nutrient source, especially for phosphorous and potassium. When integrated into a conventional system, it can be an important supplementary source. In a conventional system, compost helps meet goals of attaining a more sustainable agricultural system because it reduces the need for off-farm inputs.

### **Two ways composting aids control of plant diseases**

During the active composting phase, high pile temperature kills many pathogens and weed seeds. Most weed seeds are non-viable after only three days of temperatures of 140°F or higher.

The other mode of disease control is the action of a community of microbes that develops during the curing phase. These microbes antagonize the colonization of soil-borne pathogens in plant roots. This competition prevents pathogens from growing and infecting the root surface. In this way, the antagonistic microbes provide disease control without actually killing the pathogens (Hoitink et al 1987; Logsdon 1990). More research is needed to determine if this will be effective under local conditions.

## **Nutrient composition of compost**

It is important to know the nutrient composition of the compost being used since nutrient concentrations can vary considerably, especially for phosphorous and potassium. It is necessary to perform a lab analysis for compost nutrient content to determine the amount of nitrogen, phosphorous, potassium, carbon, and salts (it can be more complex including heavy metals and other components, if necessary). Nitrogen content will vary according to the carbon-to-nitrogen ratio of the compost feedstuff. If the ratio is poor on the carbon side, then the nitrogen in the compost will be lower. After determining the content of several compost samples, the sampling frequency can be reduced if the same feedstock is always being used.

Nitrogen concentration tends to be more uniform. Much of the nitrogen in compost is present in an organic form that is not readily available to plants.

Organic nitrogen is converted to inorganic by soil organisms in the mineralization process. Compost nitrogen mineralization is 8% to 12% per year. Mineralization is a complex process and much work remains to be done to determine how organisms of the soil foodweb behave differently in different cropping systems.

## **Composting process – 3 phases**

In the composting process, microorganisms utilize an organic substrate—such as manure, bedding, grass clippings, municipal waste—as a food source. Microbes harness the energy contained in the chemical bonds of the substrate in a process that requires oxygen and water. Heat and CO<sub>2</sub> result, and the remaining carbon skeletons are recalcitrant humic substances that are largely responsible for the soil-amending ability of compost.

### 1. Initial mesophilic phase

In the initial or mesophilic phase of composting, the population of microbes increases exponentially as readily available food sources of the substrate are metabolized. Temperatures of the compost pile gradually rise from ambient to more than 100°F.

### 2. Second thermophilic phase

The next phase, thermophilic, occurs during the next week or two when temperatures may reach 140°F to 160°F. Microbes that can endure the high temperatures of the pile are also responsible for decomposing more resistant parts of the substrate.

It is important to have adequate moisture and oxygen during this stage to maintain the high population of microbes in the compost pile. During this stage, all of the easily decomposable material will be used up, leaving only the most resistant materials.

### 3. Final (second mesophilic) phase

This is a curing period where composting slows down and the compost becomes relatively stable. During this stage, soil microbes recolonize the pile, and the formation of humic substances increases. The presence of soil microbes is important because they are responsible for the disease-suppressive qualities of compost. The curing stage begins when the compost pile fails to reheat after turning and ends when the pile approaches ambient temperature (Brady 2005).

## Compost pile management

To produce a good yield of high quality compost, several variables must be managed to provide for needs of composting microbes. The most important variables are substrate, oxygen content, moisture, and temperature.

### Substrate

Organic materials must provide the nutrients needed for microbial growth. One of the most important factors is the ratio of carbon to nitrogen (C:N). Carbon and nitrogen are both needed by microbes in the composting process. A high C:N ratio (too much carbon) means that there is not sufficient N to fulfill the microbes' needs. A low ratio (too much nitrogen) means that is more N microbes can decompose. The compost pile will have a bad odor.

Optimum is a C:N ratio of 25:1 to 30:1, but composting has been done in a range of 20:1 to 40:1. At a low C:N, the available carbon is consumed before stabilization of the nitrogen occurs, increasing the potential for loss into the atmosphere or soil. At a high C:N, a longer composting time is required without the addition of an N source. In addition to the C:N, the quality of the substrate in terms of chemical and physical composition is important. For example, carbon in compounds resistant to microbial attack (such as lignin—the chief component of wood) will be composted at a much slower rate than carbon of simple sugars.

*Substrate physical properties* that affect composting include porosity, structure, texture, and particle size. These physical characteristics affect composting through their effects on oxygen availability and surface area for microbes.

- Porosity measures air space and is determined by particle size, particle size uniformity, and air space continuity. Large, relatively uniform particles produce a high porosity, which aids in aeration of the pile.
- Structure refers to particle rigidity. Rigid particles resist the tendency for settling that causes loss of porosity during the composting process.
- Texture refers to the available surface area for microbial action. This is important because most microbial activity occurs in a thin layer of water surrounding the particles. As composting proceeds, the microbes work their way inward. Thus, composting occurs much more rapidly as the surface area of substrate is increased. However, there is a compromise because decreasing particle size to improve texture decreases porosity which, in turn, restricts air flow in the compost pile.

*Oxygen content:* Composting is an aerobic process because microbes involved require oxygen to live. Thus, it is necessary to provide an adequate supply of oxygen. This is accomplished by turning the pile of compost, using a machine or by hand. The oxygen content of the pore space in the pile needs to be at least 5%. Oxygen concentration may be monitored with an oxygen meter used for compost. Also, regular turning assures oxygen levels without need to measure it. If anaerobic (low oxygen) conditions

develop, a different microbial community will inhabit the compost pile, reducing the efficiency of process and producing undesirable chemical compounds.

**Moisture:** Moisture should be maintained between 40% and 65%—sufficient water to meet microbial needs without restricting air movement in the pores. Use a simple “feel” test to judge moisture level in the compost pile. If water can be squeezed out by hand, the pile is too wet. If a handful does not feel moist, the pile is too dry. Adequate moisture is the most common limiting compost process. Moisture can be added at the moment of turning the pile. Adding moisture with a hose to a windrow or pile is difficult because compost has insulating properties, so water will hit the surface of the compost pile and most will run down off the pile.

**Temperature:** Composting can occur at moderate (mesophilic) temperatures of 50°F to 105°F or high (thermophilic) temperatures of 105° to 150°F. It is common for compost piles to be managed for the activity of thermophilic microbes because higher temperatures are needed to kill pathogens and weed seeds. At temperatures above 160°F, even thermophilic microbes suffer and composting slows, causing the quality of the compost to decline. Temperature in the pile can be regulated by turning the pile or by the forced aeration system.

## Methods of composting

Four methods are useful for on-farm composting:

1. The passively aerated static pile method (Fig. 2)
2. The aerated static pile method (Fig. 4)
3. The turned pile method (Figs. 1 or 3)
4. The in-vessel method (Figs. 5a and 5b)

The common goal of these methods is to provide sufficient oxygen for the aerobic microbes responsible for the composting process.

In the static pile methods (1, 2), aeration is achieved by placing the compost pile over a series of pipes through which air is forced. Pipes can vary in diameter from 4 to 8 inches. Six-inch diameter is usually good to balance cost and performance. If the pipes have no holes (most of the time they don't) they need to be perforated—solid pipes don't work well. Holes can be easily drilled, spacing them 12 inches apart. Drill two lines of holes at about 5 and 7 o'clock positions (consider the bottom of the pipe the 6 o'clock position). As many pipes may be laid as are needed according to the length of the windrow. Separate pipe centers 12 to 18 inches from each other. (See Fig. 2).



photos by Mario de Haro Marti

**Figure 1.** Mechanically turning compost with tractor—the turned-pile method of composting—works well for farmers who can use tractors to turn a pile, adding porosity lost during settling.



**Figure 2.** In this finished passive aerated windrow, aeration was achieved by placing the compost pile over a series of perforated pipes 4- to 8-inches in diameter through which air is forced. The pile should be 3 feet high by 10 feet long.



**Figure 3.** Large compost turner makes turning the compost easier.

The major advantage of the static pile is the ability to process large volumes of manure in a small land area. In the turned pile method (3—Figs. 1, 3), materials to be composted are laid out in long windrows and periodically turned to provide aeration. Turn with a bucket loader (Fig. 1) or, in larger operations, with a special implement called a compost turner—there are several different types. (Fig. 3).

The turned pile method is amenable to on-farm use because it utilizes equipment already present on most farms, and the decomposition rate is hastened by more frequent turning (Dreyfuss, 1990). For in-vessel composting (4—Figs 5a, 5b), the composting is done in a container.



**Figure 4.** Compost is covered in this forced aerated static compost pile system.



**Figure 5a.** Municipal composter involves composting in an aerated 3-sided and roofed structure leaving the front wall open for delivery and pick-up of compost.



**Figure 5b.** Municipal composter, a form of in-vessel composting, combines processes from the turned pile and from the static pile techniques. It overcomes disadvantages and uses good points of each method.

### Passively aerated windrow composting

In the passively aerated windrow method (Fig. 2), the pile is aerated with perforated pipes embedded in the bottom of the pile. Aeration occurs as hot gases rise in the windrow—called the “chimney effect.” The pile should be 3 feet high by 10 feet long, with an insulating layer of finished compost on the bottom and top. Amendments such as straw and wood chips are sometimes used to improve structure, which permits satisfactory aeration without turning.

### Aerated static pile composting

The aerated static pile utilizes a blower to force air through the pile (Fig. 4). The pile should be + 5 feet high and 10 feet wide. It is underlain by a porous base of a material such as wood chips or chopped straw and is then overlain by finished compost.

Since the porous base distributes air between the pile and aeration pipe, it is important that the base not extend to the pile edge. It is common practice for the base to terminate one pile height short of the pile edge. Since the pile is not turned, the blend of materials and initial mixing are especially critical in the aerated static pile. A stiff bulking agent such as wood chips should be used to provide enough porosity to maintain aeration through the composting period. If aeration is uneven, the compost pile will have anaerobic areas containing very low quality compost. The amount of wood chips or other bulking agents will depend on the type of material being composted. Air needs to be going into the mixture, so adequate bulking agent is needed to maintain good porosity. After the composting period, wood chips are usually recovered, screened, and reused on new compost piles.

### Turned pile composting

In the turned pile method (Figs. 1 and 3), materials to be composted are laid out in windrows 3- to 12-feet high by 10- to 20-feet wide. Windrow size is largely determined by the organic substrate to be composted and the turning equipment. For example, bucket loaders can build relatively high windrows, while turning machines (Fig. 3) build low, wide windrows.

Windrows operate by passive air movement. The rate of air exchange depends on windrow porosity. Thus in a windrow of light, fluffy material, the air exchange can be much higher than



Figure 6. Finished compost is ready to apply.

in one of a relatively dense material. Windrow size should be optimized to achieve good aerobic composting throughout the windrow. If the windrow is too large, an anaerobic zone will be present in the center. If the windrow is too small, excessive heat loss will prevent attainment of the high temperatures required to kill pathogens and weed seeds.

As composting progresses, the pile settles, and much of the windrow's porosity is lost. Porosity is regained by turning the pile, which fluffs the material to restore air spaces lost during settling. Another benefit is exposure of all parts of the pile to the composting process, so that materials compost evenly and undesirable organisms (pathogens, weed seeds, and insect larvae) are subjected to the higher temperatures of the pile interior.

The need for turning is indicated when the pile temperature drops below 120°F. Take temperature measurements with a 2- to 3-foot thermometer. Measure at 50 foot intervals along the windrow. Too frequent turning prevents the pile from reaching a sufficiently high temperature for the composting process. When flies are active, the windrow should be turned at least once per week to break the flies' reproductive cycle.

### In-vessel composting

The in-vessel composting process is done within some kind of container, including municipal composters (Fig. 5b). In-vessel composting combines processes from the turned pile and

from the static pile techniques. It overcomes disadvantages and utilizes good points of each method. Some in-vessel methods currently being used include bins, rectangular agitated beds, silos, and rotating drums. Although they are less common for on-farm composting, in-vessel methods such as bins or rectangular agitated beds are used by some growers who see advantages of reduced labor, faster composting, higher compost quality, and reduced weather problems outweigh disadvantages of higher costs and more complex management (Rynk et al. 1992).

## Conclusion

Windrows, aerated piles, and aerated bins are the most commonly used composting methods for farms. Windrows composting is the simplest method and can be done with equipment already present on many farms. However, windrows composting is labor intensive because work must be done more frequently, almost daily in some cases.

Aerated static piles and passively aerated windrows require much labor when the pile is being built and when it is taken down, but very little labor is involved during the composting period. These methods are more complicated since they require the construction of an aeration system and pile construction with properly laid out insulation layers and correct choice of bulking agents. Thus, there is more that could go wrong in the use of these systems.

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