Composting on the Organic Farm

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The Composting Process

Composting is an aerobic process in which microorganisms convert a mixed organic substrate into carbon dioxide (CO_2), water, minerals and stabilized organic matter. Control of environmental conditions during the process distinguishes composting from natural rotting or decomposition (Zucconi and De Bertoldi, 1987). Controlled conditions, particularly of moisture and aeration are required to yield temperatures (120 to 140^{o}F) conducive to the microorganisms involved in the composting process (Chen and Inbar, 1993).

The extent of organic matter decomposition at any particular time is related to the temperature at which composting takes place and to the chemical composition of the organic substrate undergoing composting (Levi-Minzi et al., 1990). Because of the presence of readily degradable carbon (C), most organic materials initially decompose rapidly. Thereafter, decomposition slows because of the greater resistance to decomposition of remaining C compounds (lignin and cellulose), other environmental factors remaining constant. Generally, the higher the lignin and polyphenolic content of organic materials, the slower their decomposition (Palm and Sanchez, 1991).

Readily available (labile) organic nitrogen (N) is mineralized (converted to nitrate-N, a form that plants use) by microbial activity during the first weeks of decomposition. As the more labile organic N disappears, the most recalcitrant (resistant to microbial degradation) organic N predominates in the organic N pool, and the mineralization rate slows (Iglesias-Jimenez and

Alvarez, 1993). The predominance of recalcitrant organic C and N compounds in finished compost indicates a “stabilization” of the original organic material.

If the proper conditions exist in a newly formed compost pile, microorganisms immediately begin the process of decomposition of the organic materials, and the pile should begin to heat. Generally, proper conditions for active composting include an adequate supply of oxygen for microbial respiration (approximately 5% of the pore space in the starting material should contain air), a moisture content between 40 and 65%, particle sizes of approximately 1/8 to 2 inches in diameter, and a C:N ratio between 20:1 and 40:1 (Rynk et al., 1992. The relationship between the total amount of C in the mixed feedstocks (starting materials) and the total amount of N).

This first stage of composting lasts 1 to 2 days, during which time mesophilic strains of microorganisms (species that are most active at temperatures of 90 to 110^{o} F) initiate decomposition of readily degradable compounds. Sugars, fats, starches, and proteins are rapidly consumed, heat is given off and the temperature of the substrate rises. The pH typically decreases as organic acids are produced (Chen and Inbar, 1993).

The second stage is the thermophilic stage. When active composting is taking place, microbial activity in the pile should cause an increase in temperature in the center of the pile to about 120 to 140^{o}F. When temperatures are within this range, specific, heat-loving (thermophilic) bacteria vigorously degrade organic material. Temperatures will remain in this range as long as decomposable materials are available and oxygen is adequate for microbial activity (Chen and Inbar, 1993).

Many important processes take place during the thermophilic stage. Organic matter is degraded and particle size is reduced. Pathogens are destroyed (above a critical temperature of 131°F). Fly larvae are killed and most weed seeds are destroyed at temperatures above 145°F. The pH frequently rises above 7 as ammonia is liberated during protein degradation (Rynk et al., 1992).

JPG 17, 10 Temperatures normally remain in the thermophilic range for several weeks. Falling temperature is an indication that oxygen has become limiting for microbial activity and that the compost pile needs to be "turned" to reintroduce oxygen for renewed microbial activity. The pile can be re-mixed by hand, with a front-end loader, or with other specialized equipment to reintroduce oxygen to the pile or windrow. Alternatively, perforated pipe placed under the pile during construction can deliver oxygen through forced aeration from blowers and fans. Turning the pile also insures that materials are moved from outer portions of the pile where temperatures may be lower (than 120°F) to inner portions where they will be subject to thermophilic temperatures. Several turnings usually ensure destruction of most pathogens, weed seeds, and insect larvae.

Temperature in the pile can fall for other reasons. For example, if moisture content falls below 40%, the pile may become too dry for microbial activity. With normal temperature in the pile as high as 140°F, evaporation of water is normal and re-wetting of the pile is often required.

Temperature may also fall if the pile becomes too wet. If moisture content exceeds 65 to 70%, much of the pore space in the pile will contain water rather than oxygen. Oxygen will quickly become limiting and microbial activity will decrease (reflected by decreasing temperature). Without sufficient oxygen the pile will become anaerobic, and an entirely different set of microorganisms that function effectively without oxygen (anaerobes) will assume primary responsibility for decomposition. Unfortunately, this much slower process has many undesirable by-products, among them noxious odors (e.g. the “rotten egg” smell of hydrogen sulfide, H_2S, gas) and plant growth inhibitors (e.g. organic acids). A general rule of thumb is that the pile is too wet if water can be squeezed out of a handful of compost and too dry if the handful does not feel moist to the touch.

It is also possible for temperatures in the pile to become too hot. When temperatures reach the 150°F to 160°F range, thermophilic organisms begin to die and composting slows. If the pile is very dry, there is some danger of spontaneous combustion.

After the pile has been turned several times, temperatures gradually fall to about 100°F. Active composting is completed, and the volume of the original material is normally reduced by 25 to 50%. Decomposition continues beyond this point but at a much slower rate, and little heat is generated. When the compost pile temperature falls to that of ambient air, the compost is ready for curing (Rynk et al., 1992).

A normal curing period lasts for 30 days and helps insure against any negative consequences of application of immature compost in cropping situations; e.g. inhibition of seed germination. Less heat is generated during this period and the final pH is normally slightly alkaline. Common microorganisms (pathogens and beneficials) as well as a microfauna re-colonize the compost. Intense microbial competition for food takes place through both direct antagonism and production of antibiotics (Chen and Inbar, 1993). It is in this competition that pathogens (e.g. *Pythium, Rhizoctonia, and Phytophthora* species) are often suppressed by beneficial microbial species (Hoitink and Fahy, 1986).

No undesirable intermediate products should remain in the cured, compost product. Trace metals become tightly bound to organic matter through adsorption reactions. Ammonia concentration should fall to a level that does not inhibit root growth. Humic matter content increases as does the cation exchange capacity of the material. The C:N ratio generally decreases because C is lost from the pile as microbial activity releases CO_2. Little or no trace of the original feedstock materials should be discernible in the final product. It should be dark brown to black in color, consistent in size, soil-like in texture, and particle size should be reduced to ½ inch in diameter or less (Rynk et al., 1992).

During the composting process, N is lost through volatilization of gaseous ammonia. Losses can be substantial (as much as 50% of total N). The percentage of total N lost increases as the initial N concentration of the feedstock material increases (Douglas and Magdoff, 1991). This loss is somewhat offset by the loss in mass of the materials resulting from oxidation of organic C to CO_2. and loss of water. Nevertheless, composts (made from hog manure, for example) can be expected to contain less N than raw feedstock material.

Depending on method, management, and planned end-use, the entire composting process can take as long as six months. In some situations, curing may not be essential (e.g. topsoil replacement in severely eroded fields). In others, a completely stable end product may be critical (e.g., use in organic transplant production). Time required is primarily a function of materials and management. Highly lignified feedstocks and bulking agents and relatively large particle size lengthen time required. Easily degradable material and grinding (to reduce particle size and increase surface area) shorten the process. Active monitoring of temperature, moisture, and aeration and appropriate management responses to measured parameters, such as turning the pile or adding water, speed the process.

People composting on small farms may need to be sensitive to the concerns neighbors may have about composting operations. Noxious odors from improper processing (typically insufficient oxygen), and/or stockpiled feedstock materials, dust, noise from equipment, and fly or mosquito problems may get in the way of neighborly relations.

Compost Feedstocks

While almost any organic material can be composted, the National Organic Program Final Rule stipulates that the producer may use any composted plant and animal material, provided that they do not contain synthetic substances prohibited for crop production on the National List. The National List can be viewed at the National Organic Program website: http://www.ams.usda.gov/nop/nop2000.

JPG 11, 12 Normally, allowable materials include manures, which must be composted if crops will be harvested within 90 (aboveground crops) or 120 (root crops) before after application. Animal bedding, crop residues, yard wastes, fish and food processing wastes and byproducts, seaweed, and other products and byproducts of plant industry may be used (except as noted below).

The producer may include a mined substance of low solubility. A mined substance of high solubility may only be used if the substance is used in compliance with the annotation on the National List of nonsynthetic materials prohibited in crop production. Ashes of untreated plant or animal materials which have not been combined with a prohibited substance and which are not included on the National List of nonsynthetic substances prohibited for use in organic crop production, may be used to produce an organic crop. A plant or animal material that has been chemically altered by a manufacturing process may be used only if it is included on the National

List of synthetic substances allowed for use in organic production. The producer may not use sewage sludge or other biosolids generated from industrial processing (USDA, 2000).

The conditions in the Final Rule for producing an allowed composted material begin with the selection of appropriate feedstocks. The producer's first responsibility is to identify the source of the feedstocks used in the composting system. This requirement ensures that only allowed plant and animal materials are included in the composting process, that they are not contaminated with prohibited materials, and that they are incorporated in quantities suitable to the design of the composting system. Certifying agents will exercise considerable discretion for evaluating the appropriateness of potential feedstock materials and may require testing for prohibited substances before allowing their use. For example, a certifying agent could require a producer to inspect off-farm inputs such as leaves collected through a municipal curbside program or organic wastes from a food processing facility. Inspection may be necessary to protect against contamination from residues of prohibited substances, such as motor oil or heavy metals, or gross inert materials such as glass shards that can enter the organic waste stream" (USDA, 2000).

JPG 13 Commonly, a compost pile is created from a mixture of different feedstock materials. Blending feedstocks allows on-farm composters to create a pile with desirable C:N ratio, aeration, moisture content, and texture. The choice of feedstock materials will, of course, be constrained by availability of the material and associated handling costs. Those most economical materials are normally those that are produced on the farm itself. A bulking agent, e.g. wood chips, ground bark, sawdust or shavings, is often required to give structure to the pile and maintain adequate pore space for air movement (Hall, 1997).

Getting the correct proportions of the various feedstock materials can be challenging. The

Final Rule requires that a producer adhere to quantitative criteria when combining and managing the plant and animal materials that are being composted. These criteria are more restrictive than the general criteria for forming a compost pile discussed earlier. "When combining feedstocks to initiate the process, producers must establish a C:N ratio of between 25:1 and 40:1. This range allows for very diverse combinations of feedstock materials while ensuring that, when properly managed, the composting process will yield high quality material. The 25:1 to 40:1 range ensures that producers will establish appropriate conditions under which additional requirements in the Compost Practice Standard, most notably the time and temperature criteria, can be achieved with minimal producer oversight. Composting operations using a C:N ratio lower than 25:1 require increasingly intensive management as the ratio drops due to the risk of putrefaction. Operations in excess of the 40:1 range may achieve the minimum temperature but are likely to drop off quickly and result in a finished material that is inadequately mature and deficient in nitrogen. The producer is not required to perform a physical analysis of each feedstock component if he or she can demonstrate that an estimated value is reliable. For example, estimates of the carbon and nitrogen content in specific manures and plant materials are generally recognized. Other feedstocks of consistent quality may be tested once and assumed to approximate that value" (USDA, 2000).

Fortunately, the range of C:N ratios permitted by the National Rule allows for considerable flexibility in constructing a pile that composts properly. Other USDA "target" ranges for pile characteristics include a moisture content of 50 to 60 percent, pH of 6.5 to 8.5, and bulk density less than 1100 pounds per cubic yard (40 lbs. per cubic foot). Please note that these ranges are more restrictive than the general ranges for characteristics reported earlier.

Other feedstock characteristics to consider are resistance to decomposition, ease of handling, the potential for odor, and the presence of pathogens and other nuisances (Rynk et al., 1992). Characteristics of some potential feedstock materials for composting operations are listed in Table 1.

Many on-farm composters base the construction of a pile on personal judgement of moisture, texture, and feedstock constituents, a “rough” calculation of a mixture’s C:N ratio, as well as personal experience. However, this “trial and error” methodology may not always be desirable or effective. Often, developing an appropriate compost recipe based on some simple calculations is a better management strategy for consistently obtaining a high quality, finished product in a timely manner.

Proper proportions of feedstock ingredients can be calculated using procedures described in the <u>On-Farm Composting Handbook</u> (Rynk et al., 1992). The calculations predict the moisture content and C:N ratio of a mixture of feedstocks from the characteristics of the individual raw materials. Usually, targeting moisture content (most critical) is considered first, and appropriate proportions are calculated. Then, if necessary, the proportions are adjusted to bring the C:N ratio in line without excessively changing moisture content.

An example of a composting recipe calculation is also provided in the <u>On-Farm Composting Handbook</u> (Rynk et al., 1992). The moisture content, the percent N, and either the percent C or the C:N ratio must be known for each ingredient. Table 1 provides some of this information, but it is not a comprehensive list. Since some potential feedstocks are not included (e.g. cardboard), further research may be required. Many laboratories will analyze feedstock materials and provide composters with C;N, N concentration, percent dry matter, and other useful information.

For example, the Waste Advisory Section of the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) Agronomic Division will analyze manures and other organic materials, issue an analytical report, and provide interpretation of the results. These include total N, phosphorus (P) potassium (K), and C, C:N ratio and percent dry matter, among others. Private laboratories also offer some of these services and their fees vary (Diver, 1998). A good analytical service should always determine the concentrations of N, P, and K, as well as calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and boron (B). If C concentration is not determined, a rough estimate can be calculated from the following equation: *% Carbon = (100 - % Ash) / 1.8*.

Computer software is available that simplifies recipe calculation when three or more ingredients are used. The Cornell University website provides user-friendly spreadsheets at http://www.cfe.cornell.edu/compost/science.html (Cornell University, 1995).

Composting Methods

JPG 1 On-farm composting operations typically employ one of three composting methodologies. The first of these is a passive system where materials are placed in a pile and left alone to decompose over an extended period of time. Manure is often composted with this method. Managers may or may not use a compost recipe and adjust C:N ratio and moisture content. The piles are not aerated and often “go anaerobic” with accompanying malodors.

JPG 5, 4 A second type of on-farm composting is the windrow system. In the windrow system, a mixture of feedstock materials is placed in a long narrow pile. The pile is “turned” or mixed on a regular basis to provide oxygen, rebuild porosity (lost by settling and reductions in particle size), facilitate air movement through the pile, and exchange outer layers with inner layers in the pile (to achieve adequate treatment of pathogenic organisms and weed seeds).

The width and height of the windrows are initially sized appropriately for materials composted and for turning equipment. For denser materials (that allow less passive air movement in and out of the pile), piles might only be 3 feet high and 10 feet wide. For more porous materials like leaves, piles can be as much as 12 feet tall and 20 feet wide. One should guard against making piles too large, because (depending on the nature of the ingredients) a pile with a large cross-sectional area can have anaerobic pockets in the interior. Windrows are normally turned with front-end loaders or compost turning machines. Front-end loaders allow for taller piles, and turning machines normally produce lower, wider piles. **JPG 2**

Many factors including season, farm microclimate, temperature, moisture content, and porosity of the pile determine how often to turn the pile. Microbial activity is, of course, an important factor and is related to the age of the pile (decreasing over time as composting proceeds). Windrow temperature is the most commonly used “turning indicator.” Generally, piles are turned when interior temperature falls below 120°F (Thermometers that have a 2- to 3-foot stem are available and useful for this determination.). Measurements should be taken at about 50-foot intervals along the windrow length.

Temperatures should spike back up into the thermophilic range after piles are turned. This is critically important for meeting “processes to further reduce pathogens” (PFRP) requirements for reduction of human pathogenic organisms and vectors. As composting proceeds, the volume of windrows will be decreased, and there may be a point in time when it is advisable to combine windrows to provide adequate volume to retain heat generated in the thermophilic process.

JPG 8, 3 A third system for on-farm composting is the aerated static pile. Compost is not turned in this system; instead, air is supplied for microbial activity through perforated pipes that are placed along the bottom of windrows or piles. Fans or blowers either blow air into the piles or suck air through the piles. An insulating layer of finished compost or bulking agent normally covers each pile to retain heat and assure that thermophilic temperatures are maintained throughout the pile. This layer also helps maintain desired moisture content, discourages egg laying by flies, and serves as a biofilter to "scrub" noxious odors that may be generated by the composting process.

With this system, feedstocks are piled on top of a 6-inch base of a porous material, e.g. wood chips, chopped straw, or some other bulking agent. The perforated pipe is placed in this base material. Piles are 5 to 8 feet high, depending on feedstock, climate, and equipment. Fans deliver air to the perforated pipe, and the porous base serves to distribute the air throughout the pile. Conversely, suction in the perforated pipe collects air from the pile. When constructing the aerated pile, it is important to remember to extend the base of the pile beyond the width of the porous base. Otherwise, air will flow solely through the porous base itself and not through the pile. A good rule of thumb is that the width of the porous base should be only one-fourth to one-third of the width of the pile (of compost feedstock materials). It should stop short of the end of the pile by a distance approximately equal to the pile height. In order to assure that air is distributed evenly throughout the perforated pipe, the length of the pile should normally be less than 70 to 90 feet.

Composting is faster with this system, typically lasting 3 to 5 weeks. A detailed description of the engineering, construction, and management of aerated static systems is beyond the scope of this publication. Readers interested in more detail are referred to the On-Farm Composting Handbook.

Benefits of Compost

Introduction

Regular additions of compost to soil over time can increase soil organic and humic matter content, because composted organic matter is relatively resistant to further decomposition, i.e. contains a relatively low concentration of readily degradable C and available N. In contrast, green manures, animal manures, and crop residues are rapidly degraded when incorporated into highly weathered soils in the humid Southeast Region.

Impacts on Soil Physical Properties

Generally, the application of compost to soils improves soil structure and tilth. In addition, compost can reduce soil bulk density and soil strength, providing opportunities for deeper root penetration. Soil aggregate stability is highly dependent upon soil humus content, which can be increased with addition of compost. However, high rates of addition may be required to significantly increase aggregate stability. When incorporated, compost generally increases the cation exchange capacity of soils.

Use of compost can increase total soil porosity. Giusquiani et al. (1995) found that total porosity was greater in plots treated with compost than in non-amended control plots. Significant increases in elongated pores involved both transmission pores (50-500 µm) and pores >500 µm. Elongated pores >500 µm are essential for growth of principal roots, for drainage, and for soil aeration (especially in fine textured soils). This increases air movement into the root zone, water infiltration into soil, soil water-holding capacity, and plant available water in the root zone.

Impacts on Soil Biological Properties

Many bacteria and fungi have been identified as biocontrol agents in compost-amended substrates (Hoitink et al., 1997). Generally, these biocontrol agents suppress plant pathogens in two different ways, through either “general” or “specific” suppression. The mechanisms involved are based on competition for resources (air, water, and nutrients), production of antibiotics, hyperparasitism, and the induction of systemic acquired resistance in the host plant (in effect, inoculating the plant against the disease).

Plant pathogens, such as *Pythium and Phytophthora*, are suppressed through “general suppression.” Normally, propagules of these pathogens germinate in response to nutrients released in seed or root exudates and then infect susceptible plants. However, because of increased activity and greater biomass of the general soil microflora in compost-amended substrate, spores of these pathogens generally remain dormant and no infection takes place.

In contrast, only a narrow group of microorganisms is responsible for hyperparasitism (colonization resulting in cell lysis and death) of *Rhizoctonia solani* in compost-amended substrate. For example, *Trichoderma* spp., the predominant fungal parasites recovered from compost prepared of lignocellulosic wastes, parasitize *Rhizoctonia* species (Hoitink et al., 1997).

While heat exposure during composting kills or inactivates pathogens, biocontrol agents (with the exception of *Bacillus* spp.) are also killed by this heat treatment. Fortunately, biocontrol agents recolonize composts during curing. The raw feedstock, the composting environment, conditions during curing, and final compost utilization affect the rate of and the potential for recolonization in mature composts. In practice, controlled inoculation of compost with biocontrol agents (e.g. *Gliocladium virens* and *Trichoderma* spp.) has proved necessary to induce consistent levels of disease suppression (Hoitink and Boehm, 1999).

The decomposition level of organic matter in compost-amended substrate has a major impact on disease suppression. For example, *R. solani* compete effectively with other microbes in fresh wastes but not in mature compost with low cellulose content. *Trichoderma* spp., effective biocontrol agents of *R. solani*, are capable of colonizing fresh as well as mature compost. In fresh, undecomposed organic matter, biological control does not occur because both the pathogen and the biocontrol agent feed on abundant organic substrate. *R. solani* remains capable of causing disease. In mature compost, where concentrations of free nutrients and cellulose are low, the *Trichoderma* spp. are still active and kill propagules (sclerotia) of *R. solani*. Biological control prevails (Hoitink et al., 1997).

Compost and Plant Nutrition

Since mature compost has undergone extensive microbial degradation and stabilization, little mineralization of the remaining organic N is likely in the (cropping) year of application. Consequently, if compost application rates are based on total N in the compost, (which necessarily includes recalcitrant organic N), crops may experience N deficiency and yields may be poor. Thus, the agronomic rate of application of compost is usually dictated by the "plant-available" N (PAN) content of the compost, which is a fraction of the total compost N.

Organic N in compost is not immediately available to crops because mineralization of organic matter is a microbial process requiring time. The C:N ratio of the organic material influences microbial activity. The greater the ratio, the more limiting N becomes for microbial decomposition of organic matter . When composts with C:N ratios greater than 20:1 are added to soils, both mineral N and any subsequently mineralized, organic N can become “appropriated” by microbes (immobilized in microbial biomass), leaving plants N deficient (O’Keefe et al., 1986). Thus, the C:N ratio of compost is an important factor in the calculation of plant available N.

Soil temperature and moisture influence plant availability of organic N. Cool and/or wet weather slows microbial activity and thus inhibits mineralization processes (Aoyama and Nozawa, 1993). Consequently, mineralization may not correspond to the time when crop demand is greatest. For example, compost may not be able to supply nutrients needed at crop emergence in a wet cool spring (Dick and McCoy, 1993).

Availability coefficients are used to calculate plant available N; that is, they are used to predict mineralization in the field. In theory, if the C:N ratio of a finished compost is high (e.g. > 30) and the compost is very resistant to microbial decomposition, immobilization of compost N can be expected, and an availability coefficient could be nil (Sims, 1990). Finished composts with C:N ratios above 20 will probably have very low mineralization potential in the first cropping season; therefore, availability coefficients will be very low. At very low C:N ratios (e.g. 8 to 10) N availability coefficients may increase to approximately 0.5.

While initial immobilization of N in soil-incorporated composts is not uncommon, the C:N ratio of mature compost is commonly in the range of 8 to 14. Some compost N will become available after application for a crop . Predicting how much and when nutrients will be mineralized can be difficult albeit critical to crop performance. Rough guidelines for availability coefficients at various C:N ratios are given in Table 2.

Table 2. N Availability Coefficient Guideline for Composts

C:N	Incorporated	Broadcast
<10	0.50	0.38
10 to 15	0.25	0.19
16 to 20	0.10	0.08
21 to 25	0.05	0.03
>25	0.00	0.00

The availability of residual compost N to crop plants in the second year after addition is not well-documented. As a general rule, 10% of the remaining organic N (after one cropping season) is available for the next crop. It may take years before microbial systems support cycling efficiencies that effectively support uptake of significant quantities of nutrients from composts in the second and subsequent seasons. However, consistent, annual applications of organic matter increase available soil N over time as microbially mediated N cycling dynamics improve (Wander et al., 1994; Gunapala and Scow, 1997; Wander and Traina, 1996).

The concentration of available N in finished compost is generally lower than that in manures. As a consequence, application rates are generally higher, allowing for greater organic matter additions to soil. Thus, use of compost as a nutrient source instead of manure provides a greater opportunity to make improvements in soil physical properties.

Calculating an Application Rate

The calculation of an application rate for compost to meet crop nutrient requirements is similar to the calculation of an application rate for manure. After settling on an appropriate availability coefficient, obtaining a chemical analysis of the compost that includes total N, P, and K, and determining realistic crop N, P, and K requirements (based on realistic yield expectations for a particular soil or field), a grower can calculate a compost rate. That rate can be based on N, P, or K as the critical or priority nutrient. The amount of compost to apply is calculated from the recommended rate of the priority nutrient and the plant available-nutrient content of the compost:

That is, the amount of compost to apply equals the Recommended Amount of Priority Nutrient divided by the Plant Available Priority Nutrient (the total priority nutrient concentration of the compost X the availability coefficient).

For example, if compost contains 56 lbs. total N/ton (wet weight basis) and the availability coefficient is 0.25 (for incorporated material), then the plant available N is 56 X 0.25 = 14 lbs./ton. If the priority nutrient is N and the recommended amount of N for the crop is 140 lbs./acre, then the appropriate application rate is 140 (recommended amount) divided by 14 (plant available N) equaling 10 tons of compost per acre.

[Text Box]

Total N dry weight basis (dw) is 41,979 ppm (from lab analysis)

Compost dry matter % is 66.7 (from lab analysis)

C:N = 10 (from lab analysis)

Total N wet weight basis (ww) is 28,236 ppm (ww = dw X dry matter % in decimals)

Total N in lbs/ton (ww) = total N in ppm (ww) X .002 = 56

Availability co-efficient for compost that will be incorporated is 0.25 (Table 2)

Plant available N (PAN) = 56 X 0.25 = 14 lbs/ton

Recommended N rate for corn on a Nixonton soil is 140 lbs/acre (Hodges, 1998)

Recommended compost application rate = 140/14 = 10 tons/acre

As a general rule, availability of P and K in composted manure is somewhat higher than N.

The availability coefficient for both P and K in manure is 0.8. Crop nutrient requirements for P and K vary considerably, so when manure application rate is based on PAN, P and K may be over- or under-supplied. With vegetable crops, P requirements are somewhat lower than N requirements (on a lbs./acre basis) and K requirements are somewhat higher (Sanders, 1999). Thus, P generally tends to be over-applied and K under-applied.

It must be noted that some organic growers prefer to base nutrient management strategies on a “feed the soil” approach, building up an available soil nutrient pool. Organic nutrient additions to soil provide energy for soil microbes, increasing microbial activity. Increased microbial activity increases the nutrient cycling rate, thus increasing available nutrients for plant uptake. This strategy also attempts to build the soil to a high fertility level and then to maintain that level by replacing nutrients removed in harvested crops. Many organic growers reduce the standard “N recommendation” for a particular crop to reflect higher fertility and increased nutrient cycling in organically managed soil.

Regulatory Requirements

The National Organic Program Final Rule defines Compost Practice Standards for organic producers. In all cases a producer must manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances.

The National Organic Program Final Rule stipulates that composted plant or animal materials must be produced through a process that establishes an initial carbon-to-nitrogen (C:N) ratio of between 25:1 and 40:1 The Final Rule requires that producers “must develop in his or her organic system plan the management strategies and monitoring techniques to be used in his or her composting system. To produce an allowed composted material, the producer must use an in-vessel, static aerated pile, or windrow composting system. Producers using an in-vessel or static aerated pile system must document that the composting process achieved a temperature between 131°F and 170°F and maintained that level for a minimum of 3 days. Producers using a windrow composting system must document that the composting process achieved a temperature between 131°F and 170°F and maintained that level for a minimum of 15 days. Compost produced using a windrow system must be turned five times during the process. These time and temperature requirements are designed to minimize the risk from human pathogens contained in the feedstocks, degrade plant pathogens and weed seeds, and ensure that the plant nutrients are sufficiently stabilized for land application" (USDA, 2000).

The National Organic Program Final Rule does not contain provisions for the use of materials commonly referred to as "compost teas." A compost tea is produced by combining composted plant and animal materials with water and a concentrated nutrient source such as molasses. The moisture and nutrient source contribute to a bloom in the microbial population in the compost, which is then applied in liquid form as a crop pest or disease control agent. The microbial composition of compost teas are difficult to ascertain and control, and applying compost teas may not be permitted by the Final Rule (USDA, 2000). Growers should check at the National Organic Program website for more information on application of compost teas to organic crops.

Compost Phytotoxicity

There are problems associated with the use of immature compost. By-products from incomplete composting (e.g. organic acids that are produced as organic matter begins to degrade in "compost piles") can have adverse effects on plant growth and/or seed germination (DeVleeschauwer et al., 1981; Zucconi et al., 1981; Garcia et al., 1992; and Lynch 1978). For example, ammonia and ethylene oxide are generated when immature composts are added to soils, and these appear to play a rather important role in the inhibition of plant root growth (Wong and Chu, 1985). Normally these by-products disappear as compost matures (Wong, 1985). Many finished composts are high in salt concentration, which may also inhibit seed germination (Smith, 1992). Most laboratories that analyze finished composts provide cautionary statements when compost salinity is high enough to damage seedlings.

The rapid decomposition of immature compost may cause a decrease in the oxygen concentration of a soil and, as a result, the creation of a strongly reducing environment at the rhizosphere level. In addition to inhibiting root respiration, this may cause an increase in the solubility of heavy metals with consequent phytotoxicity (Jimenez and Garcia, 1991).

Bioavailability of Trace Metals in Compost

One of the biggest concerns when using composts for agricultural purposes is the bioavailability of trace metals or organic compounds contained in the compost product. These can accumulate in plants from root uptake or in animals from food/feed materials grown on compost-amended soils.

Organic growers are particularly concerned about the accumulation of heavy metals in soils (in particular, Cu and Zn), their bioavailability and uptake by crop plants, and the sustainability over the long-term of annual applications of composts that contain these metals. Therefore, they are well advised to monitor soil chemical properties carefully when using composts containing trace metals. Southeastern soils are typically very acidic, and Zn and Cu availability increases dramatically as soil pH decreases below 6.0 (Gupta et al., 1971; Locascio, 1978). However, Zn and Cu become very tightly adsorbed and relatively unavailable above a pH of 6.5 to 7.0 (Adriano, 1986).

Generally, trace metals and organic contaminants are very tightly bound (adsorbed) at “adsorption sites” in composts, soils, and soil organic matter, reducing both availability to plants and leaching to lower soil horizons and groundwater. Acidic, clay soils may contain large amounts of iron (Fe), aluminum (Al) and/or manganese (Mn) compounds, which coat clay particles. These compounds also provide adsorption sites for trace metal ions, including zinc (Zn), copper (Cu) and other metals. Unfortunately, the relatively sandy surface soils of the Coastal Plain offer little in the way of adsorptive surfaces for binding trace metals. That is, they contain very little organic or humic matter and do not contain the negative surface charge of clay soils. Organic matter contained in amendments decomposes quickly in well-aerated, sandy soils. Carbon compounds are oxidized to CO_2, reducing binding sites for trace metals and increasing metal availability to crops.

As composts containing trace metals are added to soils over time, total concentrations of metals necessarily increase in the soil, and, in some cases, trace metal concentration increases in plant tissue as well (Petruzelli, 1989). Little is known about the long-term availability of metals applied as constituents of composted organic materials, or whether use of these composts is sustainable over time. Little, if any, research is available from studies lasting decades and longer. A “plateau response” is the expected pattern of response to increasing concentrations of trace metals in soil from additions of composts, manures, and other organic amendments (e.g. sludges).

A plateau response suggests that metal uptake by crop plants reaches some upper limit with increasing compost application and then levels off (Corey et al., 1987). Evidence from experiments with biosolids suggests that the metal adsorption capacity added with an organic substrate persists as long as the heavy metals of concern persist in the soil (Corey et al., 1987).

In contrast, some researchers have argued that the “sludge time bomb” hypothesis is a more likely scenario for trace metal behavior in sludge- (and therefore, compost-) amended soils (Chang et al., 1997). The sludge time bomb hypothesis postulates that organic matter added along with the sludge augments a soil’s metal adsorption capacity. It is believed that this capacity, however, will revert back to its original background level with time following termination of sewage sludge application. Mineralization of added organic matter will take place with a concomitant release of metals into more soluble forms: thus a time bomb.

Compost Biomaturity

Many tests of compost maturity have been proposed. Some common are tests based on compost physical parameters. For example, does the compost pile smell bad? If so, it is likely that oxygen is limiting and the composting process is not yet complete. Has the compost temperature reached the thermophilic range and remained there for 15 days and 5 turnings? If so, the compost is probably ready to be cured for 30 days before use. Other common tests are based on compost chemical parameters (e.g. CEC, mineralization rate constants, ammoniacal N, hydrolyzable C or N, humification, humic/fulvic acid relationships). In most cases these require operator training and a substantial investment in laboratory equipment. Biological parameters (e.g. plant bioassays, germination tests, respiration indices, and relationships between biomass and total C and N) are also used. These, too, require and investment in training and equipment.

Unfortunately, none of these tests is perfect. In addition, there is variability in cost, degree of difficulty, timeliness, and reliability in the testing of different composts from different composting facilities. Because of the diversity in origin of the compost, it may be impossible to use a single method to evaluate the maturity of a given compost. Therefore, a combination of indicators is often used to determine maturity of specific composts in specific instances.

A review of the various methodologies proposed for evaluating compost maturity is beyond the scope of this publication. However, a number of the most practical or promising are presented here for the reader's consideration.

The most commonly used index of compost maturity, the ratio of total C to total N in the material, or C:N ratio, often gives misleading indications of maturity (Chen and Inbar, 1993). As has been noted above, when composts with C:N ratios greater than 20:1 are added to soils, mineral N in compost and any subsequently mineralized, organic N in compost can become immobilized in microbial biomass and made unavailable for plant uptake, leaving plants N deficient (O'Keefe et al., 1986). Even when C:N ratios are below this "breaking point", however, growers must consider the nature of the carbonaceous compounds in the compost. Many "woody" waste materials contain a relatively large proportion of carbon compounds (in particular, lignin and polyphenolic compounds) that are relatively resistant to degradation. Thus, the C:N ratio may or may not reflect a material that is sufficiently decomposed to be considered "mature." A mineralizable C: mineralizable N ratio may be a more appropriate parameter for assessing compost maturity, although these parameters are not routinely measured.

Other promising tests of compost biomaturity under development include optical density of water extracts of a compost, relatively simple respiration tests (utilizing a dissolved oxygen meter to measure changes in oxygen concentration of an aqueous compost suspension), and other spectroscopic methods (e.g. nuclear magnetic resonance, gel chromatography, etc.).

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