Using Organic Nutrient Sources

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Contents

Introduction

When using organic nutrient sources—for example, compost, manure, green manures, meals, and so forth—recommendations for crop nutrient needs will need to be translated. Soil test reports do not give specific recommendations for using organic fertilizers/amendments. This is because the percentage and availability of plant nutrients in such materials is highly variable and usually depends on its source, method of storage, and the amount and type of materials used to make the nutrient source. Generally, the low nutrient content and often limited sources of many organic materials add to the difficulty in developing a specific recommendation.

This guide is intended to help growers interpret soil test recommendations for using organic nutrient sources. Information presented applies to organic and conventional farms.

USDA National Organic Standards Summary on Soil Fertility Management

For all growers, the goals of soil fertility management are to provide sufficient nutrients to the crop grown, maintain or improve the soil condition, and minimize erosion. Organic growers are required to implement strategies to achieve these goals as indicated by USDA's national organic standards. Practices include using sound crop rotations, green manures, and cover crops and applying plant and animal matter and allowable soil amendments according to the national list.

National Organic Standards Summary for Fertilizers and Soil Amendments Use

Fertilizers and soil amendments that are in compliance with the national organic standards are available to complement other fertility practices. In addition, mined substances of low solubility can be used to supply plant nutrients. Plant or animal ashes can also be used to improve soil fertility as long as they have not been combined or treated with a prohibited substance and are not themselves a prohibited substance.

Soil Testing

Good crop yields can be expected over a rather wide range of nutrient levels in most soils. The most desirable level of each nutrient depends on such variables as the amount of rainfall, temperatures, amount of sunlight, soil texture, soil drainage, prevalence and severity of plant diseases, and the crop cultivar grown.

The more intensive the type of production, the more important the information provided by a soil test. The Agricultural Analytical Services Laboratory at Penn State analyzes soil samples for pH, calcium, magnesium, potassium, and phosphorous levels. If requested, the lab will also determine the organic matter content and salt levels of soil samples for an extra fee. Soil samples must be submitted in standard sampling and mailing kits, which can be purchased from local Penn State Cooperative Extension offices.

Other laboratories also conduct soil analysis. Whatever soil testing system is used, it is important to stick with it and develop a feel for the relationship between test results and the response of the growing crops. Crop response with balanced fertility is what really counts.

Soil Test Values

Soil test values reported from the Agricultural Analytical Services Laboratory are interpreted as "deficient," "optimum," or "exceeds crop needs" (see Figure 1.). Crops normally produce best when nutrients are present in balanced amounts at "optimum" levels. Application of a nutrient shown to be "deficient" should increase yield. When levels fall in the "exceeds crop needs" category, more than enough of a nutrient is present.

When Nutrient Levels Exceed Crop Needs

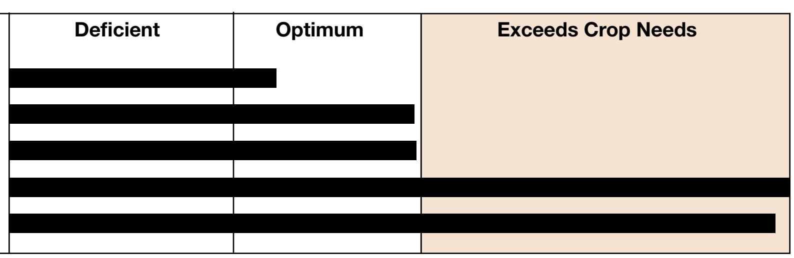
Soil nutrient levels that exceed crop needs can be as bad as deficient levels. High soil nutrient levels might not only represent an economic loss but may also result in crop, animal, or environmental problems. To achieve maximum yield and quality from each crop, a specific balance among elements is necessary. Very high phosphorus levels (above about 310 pounds P_2O_5 per acre or 140 pounds of phosphorus per acre for vegetable crops) in the soil may lead to deficiencies of other nutrients, especially of iron and zinc. If potassium, magnesium, or calcium

***Figure 1.** Example soil test report illustrating "deficient," "optimum," and "exceeds crop needs" categories for nutrient levels.*

SOIL TEST REPORT FOR:	ADDITIONAL COPY TO:

DATE	LAB #	SERIAL #	COUNTY	ACRES	FIELD ID	SOIL
11/12/2004	S00-02986		0		2122	

SOIL NUTRIENT LEVELS			
Soil pH		6.5	
Phosphate	(P_20_5)	321.0	lb/A
Potash	(K_20)	336.0	lb/A
Magnesium	(Mg0)	1813.0	lb/A
Calcium	(Ca0)	6088.0	lb/A



Recommendations for: ***SWEET CORN (FRESH MARKET)***

is high, serious nutrient imbalances can occur. When potassium levels are above about 5 percent saturation, magnesium levels 15 percent, and calcium levels 80 percent, soil nutrition is beginning to get out of the optimum range. Use best management practices to avoid increasing nutrient levels that already exceed crop needs. Yield and quality are likely to be reduced by reapplying a nutrient already present in very high amounts.

Balance and Imbalance of Nutrients in Organic Nutrient Sources

An unbalanced plant-nutrient status can be the result of using either organic or inorganic fertilizers. Most organic materials (including compost) do not contain nutrients in balanced amounts as needed by plants. In particular, many nutrients from animal sources (e.g., manure) have an excess of phosphorus and potassium relative to plant demand for nitrogen. In soil these nutrients can accumulate to levels exceeding crop needs with repeated application based on plant nitrogen needs. When using organic materials, regularly soil test to monitor phosphorus, potassium, and salt accumulation. Nutrient amendments should also be tested regularly, as similar organic materials may vary considerably in nutrient content depending on their source, handling, and conditions present when the plant or organism was living. The use of other sources of plant nutrients may be necessary to correct imbalances (for example, legume green manure crops that contribute nitrogen without increasing phosphorus and potassium).

Nutrient Availability from Organic Nutrient Sources

Suggested amounts of organic amendments or fertilizers to be applied in lieu of chemical or inorganic fertilizers may or may not be equally effective because of differences in the physical and chemical nature of organic materials. Most nutrients from organic materials are very slowly to slowly available to plants compared to inorganic fertilizers. Tables 2 and 3 give a general rating on the availability of many organic materials. Materials rated “very slow” to “medium” in nutrient availability may be used to maintain a given level and nutrient balance in the soil. Where a rapid change in nutrient levels or balance is necessary, materials having “medium” to “rapid” nutrient availability should be used.

Increasing Soil pH, Calcium, and Magnesium Levels

If soil test results indicate a need for a liming material to increase soil pH, calcium, or magnesium levels, the use of these materials is the first step in soil management. Whenever possible, a liming material should be applied during fall prior to planting to provide several months for these materials to begin reacting with soil particles. Table 1 lists materials used to increase soil pH. The liming potential of wood ashes (32 percent calcium oxide, CaO) is such that 3 pounds of wood ashes is equal to 2 pounds of ground limestone (50 percent CaO). If soil pH is 6.8 or above, wood ashes should not be used.

Decreasing Soil pH

If soil test reports indicate that the soil pH exceeds optimum, it will need to be lowered. Some materials for lowering soil pH include sulfur, peat moss, and cottonseed meal. For large areas sulfur is likely the most economical option. Elemental sulfur and iron sulfate can be used in organic production. Both of these products are labeled as “restricted” according to the Organic Materials Review Institute (OMRI), which means that they are allowed in organic production but are subject to meeting certain criteria (check with your certifying agency before using). Sulfur reacts slowly with soil particles; therefore, allow several months for changes in soil pH to occur. Whenever possible, apply sulfur well in advance of planting to provide sufficient time for reacting with soil particles.

Table 1. Materials used to increase soil pH.

Material	Calcium oxide (CaO)	Status for organic production[a]
Clam shells (finely ground)	50%	allowed
Ground shell marl (at least 75% passes a 100-mesh sieve)	35–42%	allowed
Oyster shells	43–50%	allowed
Wood ashes	32%	allowed
Limestone		
Dolomite (mined)	More than 15% MgO + 35% CaO	allowed
Calcitic	45%–50% CaO equivalent	allowed

a. Must be produced in accordance with the national organic standards to be allowable on certified organic farms. Organic status was determined through listing with the Organic Materials Review Institute (OMRI; www.omri.org) or Pennsylvania Certified Organic (www.paorganic.org). The brand of the material used may affect allowability; check with your certifier before using any product to avoid compromising your certification.

Peat moss has a pH between 3.0 and 5.0, depending on type. It is allowable in organic crop production; however, the type used cannot contain a synthetic wetting agent. Cottonseed meal is a fertilizer (see Table 3) that also has a low pH and can be used to decrease the soil pH. It is approved for organic production as long as it is not from genetically modified cotton and is free from prohibited substances. Peat moss and cottonseed meal can be expensive and are more suited for applications on small areas. For example, blueberry growers have applied peat moss in planting holes. With all these materials, it is best for organic growers to work closely with their certifying agency before applying them to ensure that organic certification is not compromised by their use.

Recommendations for Nitrogen, Phosphate, and Potash

Fertilizer recommendations for crop production are expressed in amounts of N (nitrogen), P_2O_5 (phosphate), and K_2O (potash) per acre. Recommendations from the Agricultural Analytical Services Laboratory at Penn State are given for inorganic fertilizers and expressed in units of pounds per acre (lb/A).

Adding Phosphate

A soil with a deficient phosphorus level may present a problem when relying exclusively on organic materials. Rock phosphate is the most economical organic source of phosphorus allowed in organic farming. Raw rock phosphate, even when it is from high-grade minerals and finely ground, has been quite ineffective on soils with a pH much higher than 6.0, due to low solubility and exceedingly slow reaction time. Rock phosphate needs acids to bring about the release of P_2O_5 (phosphate) for plant use; hence, it is most efficiently used on acid soils. In acid soils P_2O_5 may be available to plants in subsequent seasons following application. Although rock phosphate contains 20 to 32 percent P_2O_5, available P_2O_5 is only 5 percent.

When phosphorus is deficient it can be more efficient to add raw rock phosphate to manures or when making compost piles, rather than as a soil application. Microbial activity and localized acidity in manures and composts can increase the availability of the phosphate. However, adding phosphorus will exacerbate the previously mentioned imbalance in manures and composts. Phosphorus and nitrogen must also be considered. If manures or composts are relied on as an N amendment, over time the excess of phosphorus over N relative to plant demand will result in accumulations of phosphorus at N amendment rates. Other sources of P_2O_5 are listed in Tables 2 and 3. Before using any listed materials, it is best for organic growers to check with their certifying agency.

In planning for long-term production, apply raw rock phosphate or any other slowly available plant nutrient well in advance (at least six months to one year) of actual planting. If a high initial application of raw rock phosphate is applied, decreasing amounts will be needed in subsequent years. The increase in available phosphorus will be reflected in future soil test results.

Adding Nitrogen and/or Potash

A number of organic materials may be used to supply N and K_2O (Tables 2 and 3). Before using any listed materials, it is best for organic growers to check with a certifying agency to ensure that organic certification is not compromised by their use. Nutrient contents of the materials and the relative nutrient availabilities are listed.

Table 2. Mineral nutrient value of natural deposits useable as fertilizers.

Material	Status for organic production[a]	Nutrients (percent)[b]			Relative availability
		N	P_2O_5	K_2O	
Colloidal phosphate	Allowable[c]	0	25.0	0	Slow
Granite meal	Allowable	0	0	3.0–5.0	Very slow
Greensand	Allowable	0	1.35	4.0–9.5	Very slow
Kainite	Restricted[d]	0	0	12.0	Medium
Rock phosphate	Allowable	0	20.0–32.0	0	Very slow
Sodium nitrate	Restricted[e]	16.0	0	0	Rapid

a. Based on the Organic Materials Review Institute (OMRI) Generic Materials List (June 2004).

b. The percentage of nutrients is highly variable and differs with place of origin. Availability of nutrients from natural deposits depends largely on the fineness to which these materials are pulverized.

c. Brand used may affect allowability; check with your certifying agency before using any product to avoid compromising your certification.

d. Can be used provided it is "derived from a mined source and applied in a manner that minimizes chloride accumulation in the soil" (NOS 205.203[d][3] and 205.602[e]).

e. Cannot account for more than 20 percent of the nitrogen requirements of the crop grown. Its use is prohibited by the International Federation of Organic Agriculture Movements (IFOAM) and most other standards for organic production outside the United States.

Table 3. **Mineral nutrient value, relative availability and status for organic production of various nutrient sources. Before using any of the listed materials, it is best for organic growers to check with their certifying agency to ensure that organic certification is not compromised by their use.**

Materials[a]	Status for organic production[b]	Nutrients (percent)[c]			Relative availability
		N	P_2O_5	K_2O	
Animal tankage (dry)	Allowable	7.0	10.0	0.5	Medium
Bone meal (raw)	Allowable	2.0–6.0	15.0–27.0	0	Slow
Bone meal (steamed)	Allowable	0.7–4.0	18.0–34.0	0	Slow medium
Cocoa shell meal	Allowable	2.5	1.0	2.5	Slow
Compost (not fortified)	Allowable[d]	1.5–3.5	0.5–1.0	1.0–2.0	Slow
Cottonseed meal (dry)	Allowable[e]	6.0	2.5	1.7	Slow medium
Dried blood (dry)	Allowable	12.0	1.5	0.57	Medium rapid
Fertrell—Blue Label 1-1-1	Not OMRI listed; determined restricted by PCO[f]	1.0	1.0	1.0	Slow
Fertrell—Gold 2-1-2	Not OMRI listed, determined restricted by PCO[f]	2.0	1.0	2.0	Slow
Fertrell—Super 3-2-3	Not OMRI listed; determined allowed by PCO	3.0	2.0	3.0	Slow
Fertrell—Feed-N-Gro 4-2-4	OMRI approved	4.0	2.0	4.0	Slow
Fertrell—Feed-N-Gro 2-2-4	OMRI approved	2.0	2.0	4.0	Medium
Fertrell—Feed-N-Gro 3-2-3	OMRI approved	3.0	2.0	3.0	Medium rapid
Fertrell—Feed-N-Gro 2-4-2	OMRI approved	2.0	4.0	2.0	Medium
Fertrell—Feed-N-Gro 4-2-4	OMRI approved	4.0	2.0	4.0	Medium rapid
Fertrell—Berry Mix	Not OMRI listed; determined restricted by PCO[f,g]	4.0	2.0	4.0	Medium rapid
Fertrell—2-4-4	Not OMRI listed; determined restricted by PCO[g]	2.0	2.0	4.0	Medium
Fertrell—5-3-3	Not OMRI listed; determined restricted by PCO[g]	5.0	3.0	3.0	Rapid
Fertrell—Rock Phosphate	OMRI approved	0	3.0	0	Very slow
Fertrell—SQM Nitrate of Soda 16-0-0	OMRI restricted[h]	16.0	0	0	Rapid
Fertrell—Feed-N-Gro Omega Grow	OMRI approved	5.0	1.0	1.0	Rapid
Fertrell—Liquid #14-1-1	OMRI approved	5.0	1.0	1.0	Rapid
Fertrell—Jersey Greensand	OMRI approved	0	0	3.0	Very slow
Fertrell—Kelp Meal	OMRI approved	1.1	0.9	4.0	Slow
McGeary Organics—5-3-4	OMRI approved	5.0	3.0	4.0	Contains blood meal: rapid; soybean meal: medium; compost: slow
McGeary Organics—3-5-3	OMRI approved	3.0	5.0	3.0	Contains blood meal: rapid; soybean meal: medium; compost: slow
McGeary Organics—2-3-4	OMRI approved	2.0	3.0	4.0	Medium
McGeary Organics—8-1-1	OMRI approved	8.0	1.0	1.0	Very rapid
McGeary—Organics 6-0-4	OMRI approved	6.0	0	4.0	Contains blood meal: rapid; soybean meal: medium; compost: slow
McGeary Organics—0-2-9	OMRI approved	0	2.0	9.0	Very slow
Fish emulsion	Allowable	5.0	2.0	2.0	Rapid
Fish meal (dry)	Allowable	14.0	4.0	0	Slow
Fish scrap (dry)	Allowable	3.5–12.0	1.0–12.0	0.08–1.6	Slow
Garbage tankage (dry)	Allowable	2.7	3	1	Very slow
Grain straw	Allowable	0.6	0.2	1.1	Very slow
Guano (bat)	Restricted[i]	5.7	8.6	2.0	Medium
Kelp[j]	Allowable	0.9	0.5	4.0–13.0	Slow
Manure[k] (fresh)	Restricted[l]				
Cattle		0.25	0.15	0.25	Medium

Materials[a]	Status for organic production[b]	Nutrients (percent)[c]			Relative availability
Horse		0.3	0.15	0.5	Medium
Sheep		0.6	0.33	0.75	Medium
Swine		0.3	0.3	0.3	Medium
Poultry (75%)		1.5	1.0	0.5	Medium rapid
Poultry (50%)		2.0	2.0	1.0	Medium rapid
Poultry (30%)		3.0	2.5	1.5	Medium rapid
Poultry (15%)		6.0	4.0	3.0	Medium rapid
Marl	Allowable	0	2.0	4.5	Very slow
Milorganite (dry)	Prohibited	5.0	2.0–5.0	2.0	Medium
Mushroom compost[m]	Restricted[n]	0.4–0.7	5.7–6.2	0.5–1.5	Slow
Peanut hulls	Allowable	1.5	0.12	0.78	Slow
Peat and muck	Allowable[o]	1.5–3.0	0.25–0.5	0.5–1.0	Very slow
Pomaces[p]	Allowable				
Apple (fresh)		0.17–0.3	0.4–0.7	0.2–0.6	Slow
Apple (dry)		0.7–0.9	1.2–2.1	0.6–1.8	Slow
Castor		5.0	1.0	1.0	Slow
Winery		1.5	1.5	0.80	Slow
Sawdust	Allowable[q]	4.0	2.0	4.0	Very slow
Sewage sludge (activated, dry)	Prohibited	2.0–6.0	3.0–7.0	0–1.0	Medium
Sewage sludge (digested)	Prohibited	1.0–3.0	0.5–4.0	0–0.5	Slow
Soybean meal (dry)	Allowable	6.7	1.6	2.3	Slow medium
Tobacco stems (dry)	Allowable	2.0	0.7	6.0	Slow
Urea	Prohibited	42.0–46.0	0	0	Rapid
Wood ashes[r]	Restricted[s]	0	1.0–2.0	3.0–7.0	Rapid

a. Some materials may not be obtainable because of restricted sources.

b. Must be produced in accordance with the national organic standards to be allowable. Organic status was determined through listing with the Organic Materials Review Institute (OMRI; www.omri.org) or Pennsylvania Certified Organic (www.paroganic.org; list expires June 30, 2009). Brand used may affect allowability; organic growers should check with their certifier before using any product to avoid compromising certification.

c. The percentage of plant nutrients is highly variable; mean percentages are listed.

d. Must be produced in accordance with the national organic standards to be used in organic production.

e. Brand used must not be derived from genetically modified cotton or contain prohibited substances before soil incorporated. (OMRI, Generic List June 2004)

f. Can be applied to the soil without restriction, but must be tested for pathogens when used in foliar applications or not soil incorporated. Approval list expired June 30, 2009.

g. Must have a documented micronutrient deficiency to use. Approval list expired June 30, 2009.

h. Cannot account for more than 20 percent of the nitrogen requirements of the crop grown. Its use is prohibited by the International Federation of Organic Agriculture Movements (IFOAM) and most other standards for organic production outside the United States.

i. Must be decomposed and dried deposits from wild bats or birds. Domesticated fowl excrement is considered manure, not guano. (OMRI, Generic List June 2004)

j. Contains common salt, sodium carbonates, sodium, and potassium sulfates.

k. Plant nutrients are available during year of application. Nutrient content varies with the amount of straw and method of storage.

l. Uncomposted animal manure must be used on fields with crops not to be consumed by humans or incorporated into the soil a minimum of 90 days before harvesting a product to be consumed by humans, provided that the edible portion of the crop does not contact the soil or be incorporated into the soil a minimum of 120 days before harvesting a product to be consumed by humans that does come into contact with the soil. Using sewage sludge is prohibited in certified organic production.

m. Fresh mushroom compost is usually high in soluble salts.

n. Must be from certified organically grown mushroom production systems or be produced in a manner that prevents contamination with prohibited substances. Must meet compost requirements. (OMRI, Generic List June 2004)

o. Must not contain synthetic wetting agents. Observe worker safety precautions; use a dust mask when handling to prevent lung irritation or infection. (OMRI, Generic List June 2004)

p. Plant nutrients are highly variable, depending on the efficiency and the processing techniques at the processing plant.

q. From untreated and unpainted wood only. (OMRI, Generic List June 2004)

r. Potash content depends upon tree species burned. Wood ashes are alkaline and contain about 32 percent CaO.

s. Ash from plant and animal sources only. Use wood stove ash only if not contaminated with colored paper, plastics, or other synthetic sources. (OMRI, Generic List June 2004)

Calculating Sodium Nitrate (Chilean Nitrate) that Can Be Applied on Organic Farms

Sodium nitrate, also known as chilean nitrate, cannot account for more than 20 percent of the N requirements of organic crops in the United States. Its use is also prohibited by the International Federation of Organic Agriculture Movements (IFOAM) and most other standards for organic production outside the United States. To calculate the amount of sodium nitrate permitted, first determine the amount of nitrogen recommended for the crop. This information varies by crop and can be found on soil test reports or in production guides such as the *Commercial Vegetable Production Recommendations* guide for Pennsylvania. Next, multiply the recommended rate by 0.20 (20 percent) to determine how much of the recommended nitrogen can be satisfied by sodium nitrate.

___ lbs N recommended/acre x 0.20 = ___ lbs N/acre that can be supplied by sodium nitrate

Example:

80 lbs N recommended/acre (crop dependent; from soil test report or the *Commercial Vegetable Production Recommendations* guide for Pennsylvania) x 0.20 = 16 lbs N/acre that can be supplied by sodium nitrate

Sodium nitrate has an analysis of 16-0-0. This means that nitrogen composes 16 percent of it or, in other words, that 16 pounds of nitrogen are in 100 pounds of sodium nitrate. To determine how much sodium nitrate to apply, multiply the amount of nitrogen per acre that can be supplied by sodium nitrate by 6.25 (100 lbs sodium nitrate ÷ 16 lbs nitrogen = 6.25).

___ lbs N/acre that can be supplied by sodium nitrate x 6.25 = ___ lbs of sodium nitrate/acre to apply

Example:

16 lbs N/acre that can be supplied by sodium nitrate x 6.25 = 100 lbs of sodium nitrate/acre to apply

Therefore, if the recommendation is to apply 80 pounds of nitrogen per acre, you can apply 100 pounds of sodium nitrate per acre, which will supply 16 pounds of nitrogen per acre. The balance of the crop's nitrogen needs will need to be supplied through other nitrogen sources approved for use in organic production.

Adding Nitrogen with Leguminous Green Manures

Green manures are crops that are turned into the soil while they are young and succulent, rather than harvested. They can be grown for different purposes: adding nitrogen to the soil, suppressing weeds, scavenging nutrients left in the soil, or increasing the soil organic matter content.

Legume crops can add nitrogen to the soil. They are able to establish relationships with soilborne bacteria that are capable of extracting nitrogen gas from the atmosphere and converting it into a form that the plant can use. Seed of legumes may need to be inoculated with these bacteria; inoculants are commercially available. Inoculants are specific to the legume species grown, so chose a compatible inoculant. Also, not all brands of inoculants are allowable in organic production. Organic growers should check with their certifying agency before using.

As a result of the relationship between soilborne bacteria and legume roots, the tissues of leguminous crops have a lot of nitrogen relative to the amount of carbon,

Table 4. Approximate nitrogen credit from the use of nitrogen-fixing legumes.

Nitrogen-fixing legume	N (lbs/acre)[a]
Alfalfa sod	50–100[b]
Clovers	
Alsike	60–119[c]
Berseem	50–95[c]
Crimson clover sod	50
Ladino clover sod	60
Red	100–110[c]
White	≤130
Cowpeas	130
Fava beans	71–220[c]
Field peas	172–190[c]
Hairy vetch	50–100[b]
Sweetclovers	
Annual white	70–90[c]
Biennial	90–170[c]
Birdsfoot trefoil	40
Lespedeza	20
Soybeans	
Tops and roots	40
Grain harvest residue	15

Adapted from the *Commercial Vegetables Recommendations* guide for Pennsylvania (Penn State Cooperative Extension publication AGRS-028) and the *Northeast Cover Crop Handbook* (by Marrianne Sarrantonio, Rodale Institute)

a. Nitrogen contributed to the soil varies depending on plant biomass (volume of aboveground growth) produced. Biomass production is related to percent stand, the length of the growing season for the nitrogen-fixing legume, and management practices; table values are approximate.

b. 75 percent stand = 100-0-0; 50 percent stand = 75-0-0; and 25 percent stand = 50-0-0.

c. Use values on the lower end of the range when biomass is small and values on the higher end of the range when biomass is large.

which results in their decomposing rather quickly when turned into the soil. This results in a relatively quick release of nitrogen as the plants decompose, but the amount of organic matter added to the soil is limited over the long term. Leguminous crops differ in the amount of nitrogen they can add to the soil as shown in Table 4.

Other methods for estimating nitrogen added to the soil from a green manure crop that are more discerning for biomass production are available. Two sources for such methods are the *Northeast Cover Crop Handbook* by Marianne Sarrantonio (1994, Rodale Institute) and *Managing Cover Crops Profitably*, 3rd edition, edited by Andy Clark (2007, the Sustainable Agriculture Network).

Soil Organic Matter Content

Most crops grow best in soils with organic matter contents between 2 and 5 percent. Organic matter serves beneficial functions, including minimizing soil temperature fluctuations, serving as a nutrient warehouse, buffering the soil to changing pH, and increasing the ability of the soil to hold nutrients. Additionally, soil structure can be improved along with the ability of the soil to hold water and air. Organic matter can also provide habitat for beneficial soil microorganisms. A soil with an optimal organic matter content is better able to tolerate adverse conditions. For example, during drought conditions or when excess water is present, a soil with a good organic matter content will rebound quicker than one with a low organic matter content. The organic matter content of a soil can be analyzed as an additional test when submitting a soil sample to the Agricultural Analytical Services Laboratory at Penn State.

Mineralization

Nitrogen for plant use is released from organic matter as it is broken down by soil microorganisms, a process formally called mineralization. The rate of mineralization is influenced by many factors including environmental conditions (soil temperature, soil moisture, light levels, etc.), tillage practices (soil incorporation, depth of incorporation, timing of tillage, etc.), soil microorganism populations, and composition and particle size of the organic matter. To complicate matters, these factors also interact.

In general, mineralization will be slower at lower soil temperatures because the soil organisms involved are less active at lower temperatures. Mineralization is slower when soil is dry or waterlogged for the same reason. When organic nutrient sources, such as composts and manures, are not turned into soil and left on the soil surface, mineralization will be relatively slow due to drying. When the organic nutrient source is incorporated into the top 6 to 8 inches of soil, mineralization will occur more rapidly because this is the area of soil where most of the organisms involved in mineralization are. When the organic nutrient source is soil incorporated deeper than 8 inches, mineralization will occur more slowly because lower oxygen levels at deeper soil depths limit the number of organisms involved in mineralization.

Using Compost

Composts can be an important part of managing nutrients. In addition to adding nutrients to the soil, they can improve long-term soil quality. Composts are best when used in combination with other nutrient management strategies including green manures, other fertilizers, and crop rotations.

National Organic Standard Summary on Compost

Composted plant and animal materials can be incorporated into soil as necessary, provided the compost meets carbon to nitrogen (C:N) and temperature requirements. Compost used must have had an initial C:N ratio between 25:1 and 40:1. In addition, when using an in-vessel or static aerated pile system for composting, the pile must reach a temperature between 131°F and 170°F for a minimum of 3 days. If using a windrow system for generating compost, the pile temperature must be maintained between 131°F and 170°F for a minimum of 15 days and turned a minimum of five times during that time.

Nitrogen, Phosphorus, and Potassium in Compost

Nitrogen in compost is in two forms: the organic form and the inorganic form made up of ammonium and nitrate. Total nitrogen content can be determined by adding the organic and inorganic forms of nitrogen (organic nitrogen + ammonium nitrogen + nitrate nitrogen = total nitrogen). Total nitrogen will normally range from 0.5 to 2.5 percent (dry weight basis) in finished composts. The ammonium and nitrate forms are readily available for plant uptake. However, the organic form of nitrogen must be broken down through the process of mineralization into inorganic nitrogen for plant use (see Mineralization section for more information).

The rate of nitrogen mineralization is dependent on many factors (including, pH, depth of incorporation, compost quality and quantity, climate conditions, particle size, level of decomposition, soil microorganisms, C:N, etc.) and varies widely. Through research we know that mineralization rates vary between 10 and 50 percent a year. This means that in some years only 10 percent of the nitrogen applied through compost will be made available for plant uptake, while in other years 50 percent of the nitrogen will be made available. This rate depends on the compost as well as soil conditions; in general, compost with a low C:N ratio will mineralize at a faster rate. (For more information see next section.) Compost is most commonly applied based on the nitrogen requirement of the crop, although soils that are high in phosphorus should be limited to the phosphorus requirement. An estimation of the mineralization rate is necessary to calculate how much compost to apply. A conservative estimate is that 10 to 20 percent of the nitrogen will be available in a given year.

Composts also contain phosphorus, potassium, magnesium, and calcium. Plant availability of these nutrients in compost has not yet been established.

A typical compost might have an analysis of 1-0.7-1. Using 12.5 tons per acre of this compost applies 250 pounds of nitrogen, 175 pounds of phosphate, and 250 pounds of potassium. Additionally, magnesium and calcium will be added to the soil. Nutrient levels can quickly surpass optimum levels when using compost yearly. This is a problem for several reasons. Yields can be below optimum as a result of nutrient imbalances in the soil. Research has also shown that different weeds proliferate when certain nutrients are available in excess. Nitrogen and phosphorus buildup can also be an environmental hazard.

Carbon to Nitrogen Ratio (C:N)

The carbon to nitrogen ratio (C:N) may be used as an indicator of compost stability and nitrogen availability. Compost C:N ratios typically decrease during composting if the starting C:N ratio is >25 but may increase if starting C:N ratios are low (<15) and nitrogen is lost during the composting process. Composts with high C:N ratios (>30) will likely tie up (immobilize) nitrogen if applied to soil, while those with low C:N ratios (<20) will mineralize organic nitrogen into inorganic (plant-available) nitrogen.

Tips for Using Compost

1. Avoid the continuous use of compost or any single organic nutrient source containing more than one nutrient. Instead, use a variety of nutrient sources. This will help avoid reaching soil nutrient levels exceeding crop needs.
2. Use soil testing to keep track of soil nutrient levels. If levels exceed crop needs, avoid using compost. Instead, use a nutrient source that has no or minimal levels of the nutrient(s) in excess. Refer to Tables 2, 3, and 4 for options. One exception to this tip is that starter phosphorus may be needed for some crops when soils are cold in early spring, even when soil phosphorus levels exceed crop needs.
3. Use compost testing. Composts differ in their chemical analysis. By having it tested, it can be more accurately applied.
4. Calculate the amount of compost to apply. As noted in the Nitrogen, Phosphorus, and Potassium in Compost section, this is commonly based on the nitrogen needs of the crop unless phosphorus levels exceed crop needs. When phosphorus levels are high, calculate both phosphorus- and nitrogen-based application rates and use the lower of the two. This practice will help avoid overapplication and its associated costs: the cost of the compost, environmental costs, and loss of profits due to compromised plant health.
5. Incorporate compost in the soil. This will promote the mineralization process (see Mineralization section for more information) and minimize runoff and erosion losses.
6. If phosphorus levels exceed crop needs or it is suspected that nitrogen levels are high, minimize losses through erosion, runoff, and leaching. Environmental concerns develop when phosphorus and nitrogen reach bodies of water. Minimizing erosion by planting cover crops, using reduced tillage practices, or using grass waterways to catch and infiltrate runoff from a field can curtail movement of these nutrients.

Estimating How Much Compost to Apply Based on Crop Nitrogen Needs

Two basic methods for estimating compost application rates exist. Both methods require knowing the nitrogen content (the organic and ammonium nitrogen) of the compost. If the nitrogen content needs to be determined, compost analysis kits are available through your local Penn State Cooperative Extension office. The second piece of information needed is the nitrogen requirement of the crop to be grown. This information can be found on soil test results or in production guides such as the *Commercial Vegetable Production Recommendations* guide for Pennsylvania.

Method 1

Step 1: Determine the N content of the compost in pounds per ton.
The two values you'll need from your compost analysis report are organic nitrogen and the ammonium nitrogen (NH_4-N) from the "as is basis" column. If Penn State's Agricultural Analytical Services Laboratory performed the analysis, organic N and ammonium N will be given as a percentage. Convert organic nitrogen from percent to pounds per ton by multiplying by 20.

Organic nitrogen (%) = ___ x 20 = ___ lbs organic N/ton of compost

Ammonium N (%) = ___ x 20 = ___ lbs NH_4-N/ton of compost

Example:

Organic nitrogen (%) = 1.1 (from compost analysis report) x 20 = 22 lbs organic N/ton of compost

Ammonium N (%) = 0.16 (from compost analysis report) x 20 = 3.2 lbs NH_4-N/ton of compost

Step 2: Determine how much of N in a ton of compost will be available to the plants.
Organic N is converted into inorganic N for plant uptake through mineralization (see Mineralization section for more information). Commonly, mineralization rates between 10 and 20 percent are assumed. However, if conditions favor higher mineralization rates—for example, (1) if soil temperatures are high because of the use of black plastic, (2) soil moisture is high from irrigation and/or rainfall, (3) soil is frequently tilled, or (4) the organic matter content of the soil is high—consider assuming higher rates of mineralization. For this step multiply the amount of organic N in pounds per ton by an assumed mineralization rate. Add the amount of ammonium N in pounds per ton from step 1 to the result.

Organic nitrogen (lbs organic N/ton of compost determined in Step 1) ___ x ___ percent mineralization rate = ___ lbs available organic N/ton of compost

___ lbs available organic N/ton of compost +___ lbs NH_4-N/ton of compost (determined in Step 1) = ___ lbs available N/ton of compost

Example:

Organic nitrogen (lbs organic N/ton of compost) 22 x 0.20 (or 20%) percent mineralization rate = 4.4 lbs available organic N/ton of compost

4.4 lbs available organic N/ton of compost + 3.2 lbs NH_4-N/ton of compost = 7.6 lbs available N/ton of compost

Step 3: Determine the amount of compost to apply.
For this step first determine the nitrogen needs of the crop in pounds per acre. This information can be found on soil test reports or in production guides such as the *Commercial Vegetable Production Recommendations* guide for Pennsylvania. If you have residual nitrogen in the soil from previous nutrient applications or green manure crops, subtract that value from the recommended rate. Then, divide the remaining amount of nitrogen required by the pounds of available nitrogen per ton of compost determined in Step 2.

___ lbs N recommended/acre (from soil test report or production guide) minus any residual nitrogen ÷ ___ lbs available N/ton of compost (determined in Step 2) = ___ tons of compost to apply per acre

Example:

75 lbs N recommended/acre (assuming no residual nitrogen) ÷ 7.6 lbs available N/ton of compost = 9.9 tons of compost to apply per acre

If using a front-end loader or manure spreader with a scoop, figure out how many 5-gallon bucketfuls fit in the scoop, weigh a 5-gallon bucket of compost, and multiply to determine the weight of compost being applied per scoop.

The above method will have some built-in inaccuracy because it does not account for differences in weight due to how the compost is packed or moisture level. A second, more accurate method requires that the bulk density of the compost be determined.

Method 2

Bulk Density

This method is more accurate than the first method because it accounts for the changing moisture content of compost. It can be easier if you are using manure spreaders or front-end loaders because results are in pounds per cubic yard (lbs/yd^3). It requires determining the bulk density of the compost, which can be done in two ways. If using Penn State's Agricultural Analytical Services Laboratory to analyze compost, the lab can determine bulk density as an optional test at a current cost of $10.

Bulk density can also be determined before submitting the sample. This is more accurate than results from the lab because the lab uses less compost in its determination. The materials needed to determine the bulk density are a shovel, 5 gallon bucket and a scale (a bathroom scale will work). Fill the 5 gallon bucket half full, taking compost from various depths of the pile. Then drop the bucket 10 times from a height of about 6 inches. Fill the remaining portion of the bucket approximately half full and repeat the dropping process. Next, fill bucket to the brim and repeat the dropping process. Finally, fill bucket to the brim one more time and do not drop.

Once that is done weigh the bucket with the compost in it and record the weight.

Weight of compost and bucket = ___ lbs

Example:

Weight of compost and bucket = 40 lbs

Subtract 2 pounds (the weight of a typical bucket) from the weight above to obtain the net sample weight.

Weight of compost and bucket = ___ lbs – 2 lbs = ___ net lbs

Example:

Weight of compost and bucket = 40 lbs – 2 lbs = 38 net lbs

Next, multiply the net sample weight by 40 to convert to pounds per cubic yard.

___ net lbs x 40 =___ lbs/yd^3 (bulk density)

Example:

38 net lbs x 40 = 1520 lbs/yd^3 (bulk density)

Lastly, insert the bulk density value on the compost submission form on the line that reads "producer-determined bulk density" (lb/yd^3).

When bulk density is determined, the compost analysis report will have a third column labeled "volume basis." This is the column to use for calculating how much compost to apply using Steps 1 and 2 below.

Step 1: Determine how much available nitrogen is in a ton of compost.
Multiply the amount of organic N by a mineralization rate. Then, add the amount of ammonium N.

Organic nitrogen (lbs organic N/yd^3 of compost from compost analysis report) ___ x percent mineralization rate (estimated based on environmental conditions; see Mineralization section) = ___ lbs estimated available organic N/yd^3 of compost

___ lbs available organic N/yd^3 of compost (calculated above) + ___ lbs NH4-N/yd^3 of compost (from compost analysis report) = ___ lbs available N/yd^3 of compost

Example:

Organic nitrogen (lbs organic N/yd^3 of compost) 16.7 x 0.20 (20%) percent mineralization rate = 3.34 lbs available organic N/yd^3 of compost

3.34 lbs available N/yd^3 of compost + 0.19 lbs NH4-N/yd^3 of compost = 3.53 lbs available N/yd^3 of compost

Step 2: Determine the amount of compost to apply.
To do this, take the nitrogen recommendation and divide it by the amount of available nitrogen in a cubic yard of compost. Nitrogen recommendations can be found on soil test results or in production guides such as the *Commercial Vegetable Production Recommendations* guide for Pennsylvania. If you have residual nitrogen in the soil from previous nutrient applications or green manure crops, subtract that value from the recommended rate. Then, divide the remaining amount of nitrogen required by the pounds of available nitrogen per cubic yard of compost.

___ lbs N recommended/acre (from soil test report or production guide) minus any residual nitrogen ÷ ___ lbs available N/yd^3 of compost (from Step 1) = ___ yd^3 of compost to apply per acre

Example:

75 lbs N recommended/acre (assuming no residual nitrogen) ÷ 3.53 lbs available N/yd^3 of compost = 21.2 yd^3 of compost to apply per acre

Estimating Residual Nitrogen from Compost

Since not all the organic nitrogen in compost is mineralized in the year it is applied to the soil (see Mineralization section for more information), nitrogen will made available to plants in subsequent years. Accounting for this residual nitrogen can decrease the amount of nitrogen applied in the subsequent year, saving money and helping avoid overapplication of nutrients.

Step 1: Estimate how much organic nitrogen was used in the year compost was applied.

Take the pounds of organic nitrogen in a ton or cubic yard of compost and multiply it by the total number of tons or cubic yards applied. Then, multiply the result by the mineralization rate used when originally calculating how much compost to apply.

___ organic N lbs/ton or yd^3 x ___ tons or yd^3 of compost applied = ___ lbs organic N applied

___ lbs organic N applied x ___ mineralization rate = ___ lbs organic N available in the year the compost was applied

Example:

16.7 lbs organic N/yd^3 x 21.2 yd^3 of compost applied = 354 lbs organic N applied

354 lbs organic N applied x 0.20 (or 20%) mineralization rate = 70.8 lbs organic N available in the year it was applied

Step 2: Determine how much organic nitrogen is left in the soil.

Take the pounds of organic nitrogen applied (determined in Step 1) and subtract the total pounds of organic nitrogen available in the year the compost was applied (determined in Step 1). The result is the amount of organic nitrogen left in the soil that can undergo mineralization and be available for plant uptake in the year after the compost was originally applied.

___ lbs organic N applied (determined in Step 1) – ___ lbs organic N available in the year it was applied (determined in Step 1) = ___ organic N left in the soil

Example

354 lbs organic N applied – 70.8 lbs organic N available in the year it was applied = 283.2 lbs organic N left in the soil

Step 3: Finally, assume a mineralization rate for the organic nitrogen left in the soil.

For this step, take the result of Step 2 and multiply it by a 10 percent mineralization rate. This final result is the amount of residual nitrogen available the year after the compost was applied. This value can be subtracted from nitrogen application recommendations.

___ lbs organic N left in the soil x 0.10 (or 10%) = ___ lbs residual nitrogen

Example

283.2 lbs organic N left in the soil x 0.10 (or 10%) = 28.3 lbs residual nitrogen

Using Manure

Tables listing the nutrient contents of different manures are available; however, nutrient content varies depending on several factors, including the feed the source animal was provided, presence of bedding in the manure, and manure handling. Also, nutrient availability changes as the manure ages. Therefore, it is recommended that manures be tested for their nutrient contents. Manure is applied based on the nitrogen needs of the crop. Fact sheets are available through Penn State Cooperative Extension with detailed calculations for determining application rates for manures (for example, *Agronomy Facts 55: Estimating Manure Application Rates*).

Much of the nitrogen contained in fresh manures is in the form of ammonia or ammonium, which can be quickly lost to the atmosphere through volitalization. To avoid this nitrogen loss, raw manures should be soil incorporated when possible. Applying manure well in advance of production—for example, in the fall or as mandated for organic growers (see section below)—is recommended.

National Organic Standard Summary of Manure Use

According to the national organic standards, raw animal manures can be used when needed on fields planted with crops not intended for human consumption, such as green manures or cover crops. When raw manures are used on fields that are planted in crops for human consumption with the edible part of the crop not in contact with the soil (e.g., staked tomatoes, peppers), it must be soil incorporated a minimum of 90 days before harvest. When raw manures are used on fields that are planted in a crop for human consumption with the edible part of the crop in contact with the soil (e.g., matted-row strawberries, melons), it must be soil incorporated a minimum of 120 days before harvest. The use of sewage sludge is prohibited in certified organic production.

Additional Sources for Information

The following publications and Web sites are suggested for those who would like more information on using organic nutrient sources. Penn State publications can be obtained from through your local Penn State Cooperative Extension office, on the Web sites below, or by contacting the Publications Distribution Center at 112 Agricultural Administration Building, University Park, PA 16802; phone: 877-345-0691.

Penn State Cooperative Extension Publications

Arrington, K., C. Abdalla, D. Beegle, R. Graves, and K. Saacke Blunk. *Nutrient Budgets for Pennsylvania Cropland: What Do They Reveal and How Can They Be Used?* University Park: The Pennsylvania State University, 2007. **pubs.cas.psu.edu/FreePubs/pdfs/ua442.pdf**

Beegle, D. *Agronomy Facts 55: Estimating Manure Application Rates.* University Park: The Pennsylvania State University, 1997. **pubs.cas.psu.edu/FreePubs/pdfs/uc151.pdf**

———. *Agronomy Facts 60: Nutrient Management Planning: An Overview.* University Park: The Pennsylvania State University, 2003. **pubs.cas.psu.edu/FreePubs/pdfs/uc156.pdf**

Orzolek, M. D., E. Sánchez, W. J. Lamont, T. Elkner, K. Demchak, G. Lin, J. M. Halbrendt, B. Gugino, S. J. Fleischer, L. LaBorde, K. Hoffman, and G. J. San Julian. *2009 Commercial Vegetable Production Recommendations—Pennsylvania.* University Park: The Pennsylvania State University, 2009. Available for $16.

Other Publications and Web Sites

Clark, A. *Managing Cover Crops Profitably.* 3rd ed. Beltsville, Md.: Sustainable Agriculture Network, 2007. Available for download from **www.sare.org/publications/covercrops/covercrops.pdf**. May also be purchased for $19 from Sustainable Agriculture Publications, PO Box 753, Waldorf, MD 20604-0753; phone: 301-374-9696; **www.sare.org/publications/order.htm**.

Dougherty, M., ed. *Field Guide to On-Farm Composting.* Ithaca, N. Y.: NRAES Cooperative Extension, 1999. Available for $14 from NRAES Cooperative Extension, PO Box 4557, Ithaca, NY 14852-4557; phone: 607-255-7654; **www.nraes.org**.

Organic Vegetable Production. Ithaca, N.Y.: NRAES Cooperative Extension, 2004. Available for $28 from NRAES Cooperative Extension, PO Box 4557, Ithaca, NY 14852-4557; phone: 607-255-7654; **www.nraes.org**.

Rynk, R., ed. *On-Farm Composting Handbook.* Ithaca, N.Y.: NRAES Cooperative Extension, 1992. Available for $25 from NRAES Cooperative Extension, PO Box 4557, Ithaca, N. Y. 14852-4557; phone: 607-255-7654; **www.nraes.org**.

Sarrantonio, M. *Northeast Cover Crop Handbook.* Kutztown, Pa.: Rodale Institute,1994. Available for $16.95 from the Rodale Institute Bookstore, 611 Siegfriedale Road, Kutztown, Pa. 19530; phone: 610-683-6009; **www.rodaleinstitutestore.org**.

USDA Agricultural Marketing Service National Organic Program: **www.ams.usda.gov/nop**

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Building on *Soil Testing for the Organic Gardener* (The Pennsylvania State University, 1972) by R. F. Fletcher and P. A. Ferretti.

Visit Penn State's College of Agricultural Sciences on the Web: www.cas.psu.edu

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