Soil Fertility

Soil fertility can be defined as a soil’s capacity to produce. It is a function of soil physical, biological and chemical properties and functions. All of these (not just plant nutrients) must be considered and managed to build and maintain fertility.

When soil physical properties are favorable for plant growth, roots, water and air can move into and through the soil easily and without impediments. Key soil physical properties include soil texture and structure. Soil texture is a function of the amounts of sand, silt and clay in the soil. For all practical purposes, it can not be altered on a field scale. However, knowing the texture of a soil (not just at the surface, but also throughout the root zone and beyond) is important. Compared to soils with more clay, sandy soils tend to hold lower quantities of nutrients (e.g., they have low CEC, see below) and less water (they have larger pores) and water tends to infiltrate into, and drain out of, them more rapidly.

Soil structure is determined by how individual soil particles stick together to form “aggregate.” When clay particles, which are the smallest particles in the soil, stick together to form stable aggregates, this improves things from the point of view of a crop or a farmer. Good soil structure enhances good water infiltration and drainage, increases water holding capacity, and facilitates root growth. Soil structure can be influenced significantly by management and can be promoted by several practices, including: a. adding organic matter, b. growing grasses as cover crops or cash crops (e.g., corn, wheat), c. adding Ca++ (as opposed to Mg++ and Na+) containing minerals (e.g., gypsum, CaSO₄), and, 4. tilling minimally and at the proper moisture.

Increasing the amount of organic matter in a clay soil tends to improve soil structure, with the benefits outlined above. Increasing the organic matter of a sandy soil tends to increase the soil’s water and nutrient holding and supplying abilities.

Soil biological properties include the characteristics of the communities and activities of the micro- and macro-organisms living in the soil. Soil ecosystems tend to be very diverse and usually the vast majority of organisms in organically managed soils serve beneficial functions. However, some soil organisms can be pests; examples include plant pathogens and crop feeding insects. As a general rule, highly diverse and active soil ecosystems exhibit more efficient nutrient cycling and have fewer pest problems because no one species can dominate in such diverse systems. Additions of organic matter help promote such diversity by feeding a wide range of microbes and crop rotation helps prevent one type of organism (i.e., one that attacks a particular crop) from building up in the soil season after season.

Soil chemical properties are important in many ways. The soil is the source of most of the elemental nutrients that plants need. Key soil chemical properties which have strong influences on plant nutrient availability include pH and Cation Exchange Capacity. Soil pH values near neutrality (i.e., 6–7) are best for most crops. Outside this range, a variety of mineral deficiencies and toxicities tend to occur. Soil pH can be moderated by organic matter additions or specific mineral additions (e.g., lime, CaCO₃, to raise pH or elemental sulfur, S, to lower it). Cation Exchange Capacity (CEC) is a measure of a soil’s (or a soil component’s) ability to store, in a relatively available form, cations (i.e., positively charged ions including important nutrients such as Ca, Mg and K). Sand particles have virtually no CEC, while many clays have moderately high CECs (although there is a wide range of CECs within the different types of clays) and Soil Organic Matter has very high CEC levels. Therefore, particularly in sandy soils, the CEC of a soil can be increased by additions of organic matter. Plant nutrients can be added to the soil in a variety of ways which are discussed below.
Organic soil and fertility management focuses on managing the soil ecosystem by working the soil with care, rotating cash and cover crops with crop nutrition and pest management in mind, and adding mineral (e.g., chemically unaltered mined products) and organic (e.g., plant and animal residues and by-products) amendments. Because of the importance of soil organic matter in enhancing soil physical, chemical and biological properties, managing organic matter is central to organic farming.

**Soil Organic Matter**

Soil organic matter (SOM) is a complex of diverse components including plant and animal residues, living and dead soil microorganisms, and substances produced by these organisms and their decomposition. SOM influences the chemical, biological and physical properties of the soil in ways that are almost universally beneficial to crop production. The most common sources of SOM in farming are crop residues, cover crop residues, manures and composts. When fresh SOM is added to the soil, most of it decomposes to CO$_2$, H$_2$O and minerals (including essential plant nutrients) within a few months to years. This decomposition process is carried out by organisms (mostly microbes) in the soil, which are using the SOM as food; it provides energy (e.g., via respiration) for the microbes and mineral nutrients for both microbes and plants (e.g., crops). Some SOM is very resistant to (further) decay and can last (often bound tightly to clay particles) for hundreds of years. This very stable form of SOM is commonly referred to as humus. Humus is typically about 70% of the total SOM in agricultural soils in California. Humus, in particular, and SOM in general, are important in enhancing soil nutrient (especially cation) holding and water holding capacities, soil structure and tilth and general fertility.

Organic matter management is an important part of organic farming, but our understanding of it is quite elementary. We know that soil fertility tends to increase with increasing SOM and continual depletion of SOM eventually leads to very poor soils. However, while maintaining or increasing the organic matter content of a soil is generally desirable, our goals for SOM management should be more sophisticated than simply increasing the amount of it in the soil. In part, this is because some of SOM’s benefits (e.g., its value as a food/energy source for microbes and its release of nutrients such as N and P) are only derived from its decomposition. Under most conditions, the majority of added SOM decompose within a year or two and it is this recently added SOM that is responsible for most of nutrients that are released by decomposing SOM (although it is the much more stable humus that constitutes the majority of the SOM present). Therefore, at a minimum, good SOM management involves frequent additions of SOM so that there can be a continual breakdown of SOM without a net depletion of it.

While we do not understand SOM dynamics very well, we do know that SOM decomposition is accelerated by tillage (which increases aeration, and thus decomposition, of SOM), and by warm, moist soils with good nutrition (nutrients support the activity of microbes that break down SOM). Note, however, that warm, moist soils with good nutrition also favor plant growth. Thus, there are two opposing effects of such conditions: 1. the breakdown of SOM, and 2. the growth of plants (e.g., cash crops and cover crops), which soon become fresh SOM. Thus, depending upon a field’s history and many other factors, these conditions may lead to either a net increase or a net decrease in SOM. However, over a period of many years, continuous annual tilling of a temperate zone soil typically reduces SOM levels by about one half, compared to the untilled soil. When previously untilled land is first brought into tilled production the accelerated SOM decomposition can release large amounts of nutrients for a few years, but after a while this burst of fertility disappears and productivity drops unless remedial actions are taken.

**Determining crop nutritional needs**

Crops (and other plants) require certain elements to live and function properly. These “essential nutrients” include the macro-nutrients (C, H, O, N, P, K, S, Ca, Mg), and the micro-nutrients (Fe, Cl, Cu, Mn, Zn, Mo, Ni and B). The first three of these are supplied by air and water, but plants get the rest from the soil (almost exclusively, although we can supply some nutrient quantities via the leaves in foliar sprays).
Successful organic soil management involves enhancing soil properties generally and ensuring that the soil has sufficient available nutrients to meet all of a crop’s nutritional needs. Because many organic amendments tend to contain a wide array of different plant nutrients, such amendments help reduce the chances that specific mineral deficiencies will occur. In many organically farmed soils, most of the essential nutrients are present in amounts adequate for most crops without the farmer specifically adding them. However, one nutrient, N, needs to be added in some form for almost all (non-legume) crops. P is also frequently needed in many locations, although many California valley soils have large stores of P and P additions may be needed only rarely. Many of the other nutrients may be needed in specific situations. Therefore, knowing how to estimate and meet a crop’s nutritional needs is important to successful crop production. Crop nutrient needs can be estimated in a variety of ways. Most successful farmers use a combination of approaches. These include:

- **Farmer observation** is very important (“the best fertilizer is the farmer’s footprints”). Laboratory analysis (e.g., soil and tissue tests) can be very valuable, but without the farmer’s observations, they can be can useless, or worse. An observant farmer can notice patterns in a field that may be related to differences in soil characteristics and combine these observations with laboratory analysis soils samples taken from different areas of the field to understand the situation. Farmers can also observe changes that develop in the field during a season and note patterns that may persist from season to season. While it is true that relying solely on visual symptoms to make nutrient management decisions can lead to problems for a number of reasons (e.g., crop growth has been compromised already by the time a nutrient deficiency symptom is observable and such a deficiency may be impossible to correct mid-season), there is no substitute for the farmer spending time in the field observing what is happening.

- **Soil tests** may be useful in evaluating some important factors such as soil pH and CEC (and the relative amounts of cations such as Ca, Mg, K, Na and H on the cation exchange sites of the soil), % SOM and the levels of available P, K and Zn. Soil tests may also help identify chemical problems such as toxic levels of certain minerals. Typically soil tests are done prior to the growing season. For the factors and nutrients mentioned above, this “pre-plant” testing can work well because their levels are quite stable over periods of several months.

However, pre-plant soil tests for N are not very valuable for predicting season-long N availability. This is because N is very dynamic in the soil and the amount of available N can change rapidly as the season progresses. A pre-plant measure of the total SOM can give some idea of how much N may become available through SOM decomposition during the season (see below), but this just an estimate, because many factors influence this process. However, it is possible to do rapid, in-field soil tests to determine the amount of Nitrate-N in the soil at any given time. Since nitrate is the main form of N taken up by most crops measuring Nitrate-N can give a farmer a reasonable estimate the amount of available N at the time of sampling.

Typical soil tests for organic matter have some value, but only measure soil C and are thus fairly crude. Monitoring changes (i.e., increases or decreases) in organic matter content over time can be important in evaluating the long term effects of a soil management program. However, care should taken to avoid sampling soils for organic matter content at a time that the results will be unduly influenced by short term impacts of large organic matter additions (e.g., following incorporation of a cover crop).

The appropriate soil P test to use for most of California’s agricultural soils is the Olsen Bicarbonate Test (this test is used when pH is over 6.0, which is usually the case in California). For most warm season vegetable crops, if the Olsen test indicates 15 – 25 ppm P, there is likely adequate available P in the soil. Because P availability is lower in cool soils, Olsen test P levels of around 40 – 60 ppm P are generally recommended for most cool season vegetables. An ammonium acetate extraction is the recommended
test for soil K. If this test indicates at least 200 ppm K, there is likely sufficient available soil K and no additional K will be needed by a crop, regardless of the season.

- **Plant tissue tests** give the farmer a good idea of the crop’s nutrient status (but not why a particular nutrient may be present in excessive or inadequate amounts) and are useful for all plant nutrients. Interpreting plant tissue (and soil) tests requires research-based information on what are “inadequate,” “adequate,” and “excessive” nutrient levels in plant tissues (or soils). While this information is available for many crops in California, these levels have generally been determined using non-organic crops and, at least for some nutrients and crops, it appears that these levels need to be adjusted for organic production.

- A “nutrient budgeting” technique can be used to estimate the amount of a nutrient that is required by a crop and then develop a plan to supply that amount of available nutrient to the crop from sources such as soil reserves and various additions (e.g., cover crops, amendments and/or fertilizers). This method is particularly valuable for N. The amount of N required by a crop is function of many factors, but the crop grown is a primary one. The following list can be used as a rough guide of the N requirement for several crops in organic vegetable rotations:
  - **No N requirement**: Almost all cover crops, especially legumes; almost all organic legume cash crops.
  - **Low N requirement** (less than 120 lb/ac): Short season crops such as baby greens, radishes and single cut spinach; cucumbers; squashes.
  - **Medium N requirement** (between 120 and 200 lb/ac): carrots; garlic and bulb onions; lettuce and medium/long season greens; melons; chili peppers; tomatoes (bush tomatoes may require more in hot locations to minimize sunburn).
  - **High N requirement** (more than 200 lb/ac): large, full season cole crops (broccoli, cauliflower, head cabbage), celery, potato, bell pepper (especially in hot locations where peppers are prone to sun burn).

These requirements are typically met by N from a combination of sources such as ‘native’ SOM, cover crop residues, manures, composts and organic fertilizers. The N contribution of SOM is discussed here and the N contribution of the other sources will be discussed below. In general, we can estimate that during a season, for each 1% SOM, about 50 – 70 lb N/ac will be made available to the crop from SOM mineralization. Thus, a soil with 1.5% SOM would be expected to release 80 – 100 lb N/ac from SOM mineralization during a season. However, this amount can vary and may be lower if the season is short or soil conditions lead to low microbiological activity. Such conditions may exist in a relatively cool (e.g., winter months), wet (e.g., high rainfall year, especially in a heavy soil), or dry average soil situation (e.g., drip irrigation which does not wet the entire soil volume).

**Building soil fertility and meeting crop nutritional needs**

Successful organic soil and fertility management includes ensuring that the soil has sufficient available nutrients to meet all of a crop’s nutritional needs. Organic farming relies on feeding the soil (including the organisms in the soil) so that the soil may feed the crop. The primary methods for feeding the soil are:

- **Cover Crops**
- **Manures**
- **Composts**
- **Mineral products**
- **Animal by-products**
- **Processed and/or combined versions of the above**

In addition, other materials (e.g., foliar sprays) may be very important in supplying essential nutrients to a crop in certain situations and **crop residues** may be important in adding organic matter to the soil and recycling nutrients.
Cover crops:
1. Add relatively rapidly decomposable organic matter. 2 - 6 T dry matter/acre is typical; this is raw SOM and helps feed soil microbes and releases nutrients. High nitrogen cover crops (e.g., legumes) will decompose more rapidly than low nitrogen cover crops (e.g., grasses).
2. Add N (if legumes) or help conserve it (particularly if non-legumes). Legumes can “fix” nitrogen [i.e., take atmospheric N₂ gas and convert it into a (chemically reduced) form that is usable by plants and animals]. In California, well managed winter legumes can fix 150 - 200# N/acre and summer legumes 75 - 150# N/acre. Legumes are often an organic farmer’s cheapest source of nitrogen. Nitrogen fixation can only occur when the strain of Rhizobia present in a legume’s roots is an effective strain for that particular species of legume. Therefore, legume cover crop seed should always be inoculated with the appropriate strain of Rhizobia. Inoculants can be purchased from seed dealers and other suppliers; it is also possible to purchase pre-inoculated seed of many legumes. Nonlegume cover crops such as cereals and mustards are the most effective scavengers of nitrogen which might otherwise leach from the topsoil and pollute ground or surface waters, particularly during wet winter months.

High N cover crop residues (e.g., legumes) typically release most of their N in the first few weeks following incorporation and generally are releasing little additional N by about two months following their incorporation into the soil. Low N cover crops (e.g., grasses), on the other hand, may temporarily immobilize soil N as soil microbes need soil N to break down the low-N cover crop residue. Unless this is compensated by N additions from other sources, this can lead to an early season N deficiency in a subsequent cash crop. However, after a few weeks, net N release usually begins to occur. Thus, a cover crop mixture of grasses and legumes may be able to supply more evenly available N although we are just beginning to learn if we can effectively put this concept into practice.
3. Improve soil structure and soil-water relations and prevent (or reduce) winter run-off, erosion and nutrient leaching.
4. Require management and time (a growing season) and cost money to grow.

Below are descriptions of the more commonly used cover crops in California vegetable production.

**Winter Annual Cover Crops** - most common cover crops in California, generally rainfed

A. *Legumes*
1. *Vetches* - usually best N fixers; may add 100 - 200 lb. N/A; vigorous, viney, help suppress weeds; *‘Lana’ wooly pod vetch* - most growth and N in moderate moisture regime; *Purple vetch* - nearly as good and better under very wet conditions; *Common vetch* - least vigorous, but produces nectar, may attract beneficial insects.

2. *Field Peas* - various types; not quite as vigorous as vetches usually, but can add similar amounts of N
3. *Fava/Bell beans* - upright, not very competitive with weeds; about half as productive as vetches usually, but easier to work in (not viney) and may attract beneficial insects

B. *Non-legumes*
1. *Grasses* - don’t add N, but lots of relatively stable biomass; low N content may lead to soil N immobilization after incorporation; help improve soil structure and tilth; annual fescues and bromes tend to mature sooner than cereals such as oats, barley and rye.
2. *Mustards* - also don’t add N, but residue has higher N content than grasses so don’t immobilize N as readily; typically have tap root and break down quite quickly

**Summer Annual Cover Crops** - less common than above; require irrigation

A. *Legumes* – this group dominated by black eyed peas (cowpea), but others may perform well also.
1. *Black eyed peas* - fairly drought tolerant; may fix 80 - 120 #N/A; vigorous, viney, suppresses weeds
2. *Others* - *Hyacinth bean, Sesbania, Crotalaria* - generally as productive as black eyed pea, but less well known; latter two are upright, not very competitive with weeds.

B. *Non-legumes*
1. *Sorghum, sudangrass and their hybrids* - grow very fast in hot weather; may produce 6T/A if dry matter in only 8 - 9 weeks; very competitive with weeds; very low N content; can immobilize N in soil.
2. Buckwheat - likes moderate temperatures, not heat; tends to yield little, but produce lots of flowers that may attract beneficial insects

*Manures* can be a source of important nutrients such as N, P, K, Ca and others, as well as rapidly decomposed organic matter. Manures may also have some undesirable characteristics, such as weed seeds, diseases (plant, animal and human) and unacceptable concentrations of salts or other potentially harmful chemicals. According to NOP requirements, manure can be applied in a “raw” (i.e., not composted or “processed” – see next paragraph) state directly to a field only if it is incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with the soil surface or soil particles, or not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles. These requirements are designed to prevent contamination of food with pathogens that may in the animal manure. (If the crop is not for human consumption, there is no minimum time requirement.) However, raw manures (especially those with high mineral contents) can be harmful to plants (especially young ones) so it is recommended to make applications of raw manure to annual crop fields several weeks before planting.

According the NOP, there are two possible ways to ‘treat’ manure to avoid the time requirements outlined above: composting and processing. Proper composting of manure can eliminate problems such as weed seeds and plant, animal and human pathogens (see *Composts*, below), primarily because of the high temperatures that are generated during composting. However, composting also tends to significantly reduce the amount of *readily available* nitrogen (see *The Behavior Nitrogen in Organic Amendments*, below). In 2007, the NOP ruled that “processing” could be used as an alternative to composting. According to this ruling, a “processed” manure product has been treated so that all portions of the product have reached a minimum temperature of either 150°F (66°C) for at least one hour or 165°F (74°C), and are dried to a maximum moisture level of 12%. It is also possible to use another “equivalent heating and drying process” that would adequately (this is defined in the ruling) reduce the amount of specific bacteria in the end product.

The nutrient content of manure is influenced by the type of animal, its feed and how the manure is handled prior to application. Concentrations of nutrients found in manures can vary greatly. However, in general, nutrient concentrations tend to decrease as one goes from poultry manure to cattle manure to sheep manure to horse manure. For N in particular, the availability of nutrient that is present in the manure can vary greatly as well. The portion of total N that is available to a crop tends to be higher when total N content is on the high side and the material is relatively ‘fresh;’ Although poultry manure may be contain higher nutrient concentrations than these, typical nutrient concentrations for many manures are generally:

- N: 1.0 - 3.0% (or more in fresh manure)  
- P: 0.3 - 1.5%  
- K: 2.0 - 3.0%  
- Ca: 2.0 - 6.0%

*Composts* have many potential benefits. However, composts are also highly variable and it is important to know as much as possible about the compost that one is using. A compost’s characteristics are a function of the starting materials that went into it and the composting process used in making it. According to the NOP, a compost which includes any manure should:

- a. have an initial C:N of between 25:1; and 40:1; and,
- b. maintain a temperature of between 131°F and 170°F for 3 days (using an in-vessel or static aerated pile system) or maintain a temperature of between 131°F and 170°F for 15 days during which the material must be turned a minimum of five times (using a windrow system).

In general, composts:

1. **Add relatively stable organic matter** (not pure humus, but more stable than the raw organic materials that were the starting materials for the compost). In general, the longer the period of composting, the more stable the organic matter and the more stable the organic matter, the less rapidly it decomposes further and serves as source of energy and nutrients for soil microbes and plants.
2. **Add plant nutrients.** Composts typically have all of the nutrients needed by plants, but their concentrations may vary considerably in different composts. Compost starting materials have a very strong influence on ultimate nutrient content of the materials. Composts made from manures and other materials that have medium to high nutrient concentrations typically have concentrations of macro-nutrients such as N, P, K and Ca that are in the range of 0.5 to 2 percent (although these concentrations can still vary greatly). Composts made from woody material (e.g., many made primarily from green waste) tend to have relatively low nutrient contents. Because composts can be so variable, farmers should obtain a chemical analysis of the composts they use. Many of the plant nutrients (e.g., calcium, magnesium and potassium) present in composts are in forms that are readily available to plants. Composts also compare favorably with other phosphorous sources in terms of P availability to crops.

3. **Add nitrogen.** Contrary to many farmers’ apparent beliefs, well-made, mature composts are not a good source of rapid-release nitrogen. The total nitrogen content of manure-based composts is typically between 1% and 3%, but the amount of this that may be available to a crop in the first season is highly variable and may be as low as 20% or less. (See discussion of the Behavior Nitrogen in Organic Amendments, below.)

4. **Add beneficial microbes to the soil and supply a food source for them.** Composts help promote a diverse soil microbial community. This may help stabilize the soil ecosystem and reduce problems with certain soil-borne plant pathogens.

Composts are typically applied at rates of 3 to 6 T compost/acre/season. If applied each season at these rates most composts would typically supply all (or nearly all) of the non-N nutrients needed by crops.

**Mineral products** typically provide relatively slow-release specific nutrients (to both microbes and crops) over a period of years. In general, the NOP allows the use of mined substances (e.g., rock phosphate), but not chemically altered (i.e., synthetic) products (e.g., superphosphate, which is the product of treating rock phosphate with sulfuric acid). However, minerals which have been partially “biologically digested” (e.g., rock phosphate that has been added to a compost pile) are not considered synthetic and are thus allowed. Mineral products such as lime and sulfur can also be used to adjust soil reaction (S lowers pH; lime raises it). Typical application rates for mineral products are a few tons per acre, with applications once every few years.

**Animal by-products** (e.g., blood meal, bone meal, feather meal and fish byproducts) tend to be fairly high analysis materials with variable levels of crop availability. Most of these products are derived from the livestock, poultry or fishery industries. Their higher than average nutrient analysis facilitates shipping, handling and application and make them attractive to growers wishing to add significant amounts of specific nutrients. However, the cost per pound of nutrient can be rather high.

**Processed and/or combined versions of the above.** With the recent growth of the organic industry, increasing numbers of products are being developed and marketed that are processed from the above materials, particularly animal by-products. These products typically have relatively high concentrations of fairly rapidly available nutrients and may be marketed much like conventional fertilizers (e.g., as a starter fertilizer). These products also tend to be easy to work with and relatively expensive per pound of nutrient. However, used as supplemental materials, and not the primary source of nutrients, they may have an important role in organic systems.

**Specific nutrients and sources**

Following is a list of some of specific elemental nutrients plants that may be needed in an organic farming system and the most common amendments and methods used to supply them.

**Note:** While these generic products may be allowed, some specific formulations or brands of these products may not be. Always check with certification organization before purchasing and applying amendments.
N cover crops (legumes), composts, manures, fish meal and fish emulsion, feather meal, blood meal, cottonseed meal, Chilean nitrate (use of this product restricted by NOP)
P compost, manure, rock phosphate, bone meal
K manure, compost (esp. poultry), mined potash, wood ash, langbenite (Sul-Po-Mag), greensand
Ca gypsum, lime, rock phosphates, bone meal, oyster (etc.) shells
Mg Epsom salts, langbenite, dolomitic lime
S elemental sulfur, gypsum, langbenite
Minor elements compost, kelp products, chelates, “rock dust”

The Behavior Nitrogen in Organic Amendments
Nitrogen in organic amendments can be present as:
a. mineral nitrogen (e.g., nitrate and ammonium), which is quite available to plants, and
b. organic nitrogen (nitrogen contained in organic molecules, such as proteins and humus) which is largely only available to plants as the organic molecules break down - a process which can take a long time if in highly resistant molecules, such as humus.

If incorporated into the soil, organic amendments with N concentrations below 2% (i.e., C:N ratios over ~20:1) will often temporarily immobilize (“tie-up”) soil nitrogen. Amendments with N concentrations about 2% or more (i.e., C:N ratios below ~20:1) generally release some nitrogen soon after incorporation, but the rate of release is strongly influenced by the amount of nitrogen in the mineral forms and the relative ease of decomposition of the amendment. Many nitrogen-rich organic materials, such as most fresh manures, have a relatively high proportion of their nitrogen in mineral forms (this is sometimes detected by an ammonia smell) and/or have a high decomposition rate when first incorporated into the soil. Therefore, a relatively large percentage of the N in these materials becomes available to the crop fairly soon after incorporation. However, when manures and other organic materials are thoroughly composted, the majority of the mineral nitrogen is converted into organic N contained in increasingly complex and resistant to decay organic molecules. Thus, if incorporated into the soil, manure that is fresh or only partially composted will typically release 30 to 70% of its nitrogen as available mineral forms during the first season. However, a fully composted manure would typically release only 5 - 20% of its nitrogen as mineral forms within the first season following incorporation. In both cases, more nitrogen will be released in subsequent seasons as more organic nitrogen is mineralized. When manure or compost is surface applied (i.e., not incorporated), the same principles are at work, but the results will be different. Unincorporated manures and young composts with relatively high concentrations of mineral nitrogen may lose a lot of their nitrogen through volatilization of ammonia gas into the atmosphere (not good for maximizing N benefit of the compost/manure, nor for the atmosphere - “take-home” lesson: if using fresh manure, incorporate as soon as possible). On the other hand, well aged composts or other amendments with low mineral nitrogen contents (or amendments with high C:N ratios) will neither tie-up soil nitrogen nor release much nitrogen through ammonia volatilization if left unincorporated on the soil surface.