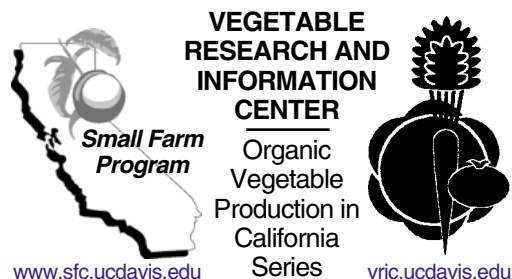


# SOIL FERTILITY MANAGEMENT FOR ORGANIC CROPS



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Specific information on organic vegetable production practices in California is scarce, and growers need sound information to guide their management decisions. The Organic Vegetable Production in California Series is made up of publications written by Farm Advisors and Specialists from the University of California's Division of Agriculture and Natural Resources. Each publication addresses a key aspect of organic production practices applicable to all vegetable crops.

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Organic vegetable production systems are guided by an overriding philosophy of "feed the soil to feed the plant." This basic precept is implemented through a series of approved practices designed to increase soil organic matter, biological activity, and nutrient availability. Over time, adding organic materials such as green manure, crop residues, and composts to cultivated soils builds levels of soil organic matter. As soil organic matter increases, the ability of the soil to supply nutrients to crops also increases. The ultimate goal is a healthy, fertile, biologically active soil with improved structure and enhanced nutrient availability.

Many soil amendments and fertilizers commonly approved for organic production systems have appreciable amounts of nutrients, but only a portion of these nutrients are available to the current crop. Organic soil fertility programs are designed to maintain adequate levels of nutrients in the soil nutrient pool and to augment the pool as needed. Management practices strive to optimize diverse biological processes in the soil to create a complex environment that ensures adequate nutrition to the crop. For a discussion of related soil management practices, see *Soil Management and Soil Quality for Organic Crops* (UC ANR Publication 7248).

## ROLE OF ORGANIC MATTER AND HUMUS

The increase of soil organic matter to optimum levels is a key aspect of any organic production system. Native organic matter levels are relatively low in California soils, generally ranging from less than 1 percent to a little more than 2 percent, and organic matter levels fall when the soil is brought under cultivation. Studies have shown that it is unreasonable for a grower to expect to increase soil organic matter by more than about 1 percent, but a relatively small increase can dramatically improve the soil fertility environment in a given field.

Soil organic matter improves cation-exchange capacity and serves as a reservoir of nutrients for the growing crop. Incorporation of organic matter, also improves soil aeration, drainage, and water-holding capacity.

Green manure crops are an economical means for elevating soil organic matter and providing nitrogen for the succeeding crop. They also reduce soil erosion and may offer benefits related to pest and disease suppression. When green manure is not practical (for example, where winters are mild and production is oriented toward early or late markets), composts and other approved amendments are useful. Compost is a relatively economical organic source of nutrients, but different composts can be quite variable depending upon the source. Growers need to understand the factors that contribute to compost quality.

The decomposition of organic matter in soils can provide much of the nitrogen (N), phosphorus (P), and sulfur (S) needed for crop nutrition. A portion of the N from many organic amendments is converted readily into available mineral forms. Phosphorus from organic amendments reacts quickly, is bound to soil minerals, and moves very little from where it is placed. Potassium (K), calcium (Ca), and magnesium (Mg) are relatively soluble from plant residues or soil organic matter fractions and also contribute to the soil pool of these nutrients. Organic matter is also a valuable balanced source of many minor elements. Organic matter releases nutrients as it decomposes and provides slow, constant availability.

Soil organic matter contains a number of fractions that vary in composition and activity. *Humus* is the most resistant and mature fraction of soil organic matter. It is very slow to decompose and may last for hundreds of years. Residues that are slow to decompose (such as hay or corn stalks) are more efficient producers of humus than are more readily decomposed materials

such as green manure residues. However, relatively little is understood about the benefits of humus or other specific organic matter fractions for crop growth, and an organic grower's crop management efforts should be directed toward increasing total soil organic matter.

## HOW TO DETERMINE NUTRIENT NEEDS

A crop's growth requirements and the supply of nutrients available in the soil determine soil fertility needs. A soil fertility program for vegetables strives to make a sufficient quantity of nutrients available to the crop so that nutrients will not be a limiting factor with regard to yield and quality. Soil testing is essential for the assessment of nutrient levels, and often is required for organic certification. Fertilizer recommendations based on soil tests are site- and crop-specific and are usually adapted from conventional (non-organic) fertilizer trials. In rare cases, this information may be complemented by specific field data gathered from organic operations, but few controlled field trials have been conducted to determine crop response to organic fertilizers in organic production environments. A soil test generally is not a reliable indication of N availability or N fertilization requirements.

Management of nutrients such as P, K, S, Ca, and Mg should be directed toward raising these nutrients to optimum levels in the soil nutrient pool as determined by a soil test. Many cultivated soils in California have relatively high levels of P, K, S, Ca, and Mg. Infrequent broadcast additions of these nutrients often are made before planting to ensure their availability and to prevent their depletion in the soil pool. When soil tests indicate nutrient imbalances (e.g., unfavorable Ca:Mg ratio), the grower may need to apply individual nutrients.

Nitrogen, however, is different. Nitrogen moves out of the soil nutrient pool in several ways. Nitrate-N is soluble in water and is easily leached from the root zone. Nitrogen may become temporarily unavailable from immobilization or tie-up by soil microbes, especially where large amounts of organic carbon are added in the presence of nitrate-N. Nitrogen may also be lost through volatilization of gaseous N from the soil surface. Denitrification, the conversion of nitrate-N to N gas, is a problem in poorly aerated or wet soil conditions.

Soils mineralize nitrogen during microbial transformation of organic matter, releasing available N at rates as high as 1 to 2 pounds of N per acre per day. With fast growing vegetable crops, however, the rate of mineralization may be inadequate for the nutrient needs of the crop. Then it may be necessary to apply fertilizer N from organic fertilizer sources. The fertilizer will typi-

cally be applied as a combination of preplant and subsequent banded and incorporated applications. Short-season crops such as leafy greens, beets, and radishes may produce well with residual N from a green manure crop or from preplant incorporated applications alone. Longer-season crops—those that remain in the field beyond 6 to 8 weeks—will need supplemental side-dress applications of N fertilizer. Liquid or soluble materials such as processed liquid fish, liquid soybean meal, or sodium nitrate may also be applied through drip irrigation systems.

Crop quality may be as important to the grower as yield with many vegetable crops. With fresh vegetables, soil fertility management often is directed at improving size, color, and uniformity. High levels of available N are especially important when produce quality is a concern. Additional P may also be needed in cold, wet soils because root growth is slow in such soils and the young seedlings cannot take up P quickly enough from a limited soil volume. Crop quality or yield may improve with a banded application of a P source even when P levels are high in the soil.

## NUTRIENT SOURCES

*Cover crops.* Growing a green manure crop that includes a N-fixing legume is the most economical way to provide N to a succeeding crop. The amount of N contributed depends upon the species and vigor of the green manure, and ultimately on the duration of its growth cycle. Typically, a green manure crop will require approximately 120 to 160 days of growth to fix between 100 and 200 pounds of N per acre. Recent research suggests that the available N from a green manure increases over a four- to six-week period following incorporation, and then returns to pre-incorporation levels. Therefore, crops following a green manure rotation may require additional applications of N later in the season.

Nonleguminous cover crops will not contribute N, but they may trap soluble nitrate-N and prevent losses from percolation and runoff. These cover crops and green manure crops may also harvest N, P, or K from deep in the soil profile and make them more available to the succeeding crop.

*Compost.* Compost is a relatively cost-effective commercial organic source of N. Compost also provides P, K, Ca, Mg, S, and other minor nutrients in fairly well-balanced amounts. Although actual concentrations of P and K in compost are low, the total additions may be quite high due to the high volume of material applied. When applying compost, the challenges are to know and understand its composition and to determine how to use it most efficiently. The grower should under-

stand the composting process used by the supplier and know the sources of raw material used. If the materials that are being composted are low in nutrients, the compost will have a low nutrient analysis. Poor-quality or immature compost may actually tie up nitrogen in the soil and decrease the availability of N to the growing crop. The carbon-to-nitrogen ratio (C:N) of a compost is one indication of the maturity and N availability. As the C:N ratio rises above 20:1, the tendency for N from the soil to be tied up increases. A compost with a C:N ratio of less than 20:1 will generally release N to the succeeding crop. Other quality considerations are age, particle size, pH, salt concentration, and purity (the volume of soil, sand, and other nonorganic materials mixed with the compost). Because compost analysis is based on dry weight, moisture content will add to the compost's weight and lower its nutrient analysis. It is not unusual for a commercial compost to have a moisture content of 25 to 30 percent.

*Manure.* Fresh or aged animal manure can also be a balanced source of N and other major and minor nutrients. Fresh manure may be of limited use because of relatively high transport costs, the potential for pollution problems, and the potential for crop injury. Another potential limitation with manure is the availability of a consistent supply of a material that is uniform enough to be confidently incorporated into a production program. Organic certifying agencies may limit the type or timing of applications of manure on organic production fields. A public perception of increased food-safety-related problems relating to manure fertilization might further limit the use of manure.

*Other commercial organic fertilizers.* A number of approved organic fertilizers are available commercially (Table 1). Many of these materials are by-products of fish, meat, and soybean processing industries. The commercial formulations and nutrient analyses of these materials vary considerably. In general, they range from 1 to 12 percent N and provide P, K, or both along

with N. The real cost of one of these materials or of compost is determined by the cost per unit of a nutrient (with correction for moisture content) multiplied by the number of units of that nutrient needed for a particular crop. The short-term availability of nutrients can vary among these materials and will also affect the amount of material required and the ultimate cost-benefit determination for applying the material.

The short-term availability of nutrients depends largely on the nature of the fertilizer material and how it was processed. In general, most of these fertilizers should be applied and uniformly incorporated prior to planting. They also may need to be applied and incorporated in one or more supplemental side-dress applications depending upon the growing cycle of the crop. Dilute liquid "teas" from these materials are sometimes applied to the soil or sprayed directly on the plant in an effort to improve nutrient availability, but the value of these teas as a nutrient source has not been clearly established.

Other simple fertilizer materials that for the most part offer only one macronutrient include:

- sodium nitrate (mined) (N)
- blood meal (N)
- rock and colloidal phosphate (P)
- potassium sulfate (mined) (K)
- green sand (K)

Certain by-products of the meat processing industry, such as blood and bone meal, have recently come under scrutiny because of food safety concerns and the potential for disease transmission. Mined Chilean sodium nitrate, a source of N, has been an important component of organic fertilizer programs because of its low cost, solubility, and ease of use. However, some certifiers restrict the use of sodium nitrate because of the long-term adverse effect of sodium on soils.

*Minor element sources.* Organic fertilizer sources commonly contain one or more minor elements. Additional

**Table 1. Common organic fertilizer materials and their approximate analysis (dry weight basis).**

|                                | Nitrogen (N)  | Phosphorus (P) | Potassium (K) |
|--------------------------------|---------------|----------------|---------------|
|                                | ----- % ----- |                |               |
| Fish meal or powder            | 10–11         | 6              | 2             |
| Chicken manure                 | 2–3           | 1.5            | 1.5           |
| Processed liquid fish residues | 4             | 2              | 2             |
| Feather meal                   | 12            | 0              | 0             |
| Seabird and bat guano          | 9–12          | 3–8            | 1–2           |
| Alfalfa meal                   | 4             | 1              | 1             |
| Cottonseed meal                | 6             | 0.4            | 1.5           |
| Soybean meal                   | 7             | 2              | 1             |
| Bone meal                      | 2             | 5              | 0             |
| Kelp                           | <1            | 0              | 4             |

synthetic fertilizers may be permitted by a certifying agency in specific circumstances for correction of minor element deficiencies. Application of approved source materials will raise soil levels to a range where they are not deficient. A number of liquid materials and teas are also available that provide one or more minor elements. Some of these may be used in irrigation systems or applied to foliage. Field trials evaluating the effectiveness of minor-element foliar applications when soil levels are already adequate do not show a consistent pattern of crop response. Costs for these materials vary widely, and the value of the material in a specific situation will often depend upon its cost. Some synthetic minor element fertilizers may contain hazardous materials used as fillers or other contaminants, and there is debate over use of these materials, even in small amounts, in organic production systems.

*Special-purpose fertilizers.* Specific approved nutrient sources of K, Ca, and Mg may be useful to an organic grower when a deficiency or imbalance is indicated by a soil test. Materials such as gypsum, lime, and potassium magnesium sulfate have been in use in agriculture for many years and their value is thoroughly tested. These materials may be used to correct deficiencies or imbalances of potassium, calcium, or magnesium, and lime may be used to raise soil pH. Gypsum also is often applied to replace exchangeable sodium prior to leaching a high-sodium soil or to improve water infiltration on clay soils with poor structure.

Growers and researchers are still evaluating a number of other special-purpose fertilizers and growth enhancers. Materials derived from kelp and other processed seaweed contain nutrients and often plant hormones and growth regulators. Some claim that microbial soil stimulants enhance growth or reduce soil pests. Brix mixes, humates, foliar nutrient and sugar solutions, and other materials are applied to raise nutrient or sugar levels (°Brix) in plant sap in an attempt to improve the plant's resistance to pests. Little replicable scientific information exists to clearly establish the efficacy or cost-benefit balance for these materials in crop production.

## CHARACTERISTICS OF ORGANIC FERTILIZERS

Organic fertilizer materials share a number of characteristics that distinguish them from conventional fertilizers. The key features to consider in a fertility management program are bulk, nutrient availability, and uniformity.

*Bulk.* Many organic fertilizer materials (e.g., compost or aged manure) are generally less concentrated sources of nutrients than are conventional fertilizers.

Application volumes for these materials may be as high as 2 to 20 tons per acre or more. Growers need to consider how they will transport, store, and apply such large quantities of material. Larger storage facilities and special handling equipment may be necessary. A high moisture content will add to the material's bulkiness. On the other hand, bulk applications of organic materials contribute appreciable quantities of organic matter to the soil and benefit soil tilth.

*Nutrient availability.* Organic fertilizers often include both a relatively small proportion of soluble nutrients and another nutrient fraction that is either unavailable to the plant or available only gradually over time. These materials as a group need to be applied earlier in anticipation of plant nutritional requirements, often two to four weeks before nutrients will be needed. The availability of nutrients will depend upon microbial activity and a lack of mixing, or extremes of moisture or temperature will also retard microbial turnover. The composition and particle size of the material can also be determining factors in the rate of microbial decomposition and nutrient availability. A more concentrated, finer-textured material generally will decompose and release its nutrients more readily than a coarser mixture.

*Uniformity.* Organic fertilizer materials as a group vary considerably with respect to particle size, moisture content, nutrient content, and nutrient distribution. Some of this inconsistency is inherent in the materials because of the nature of the production process and the fact that they are organic materials that continue to change during transport and storage. Materials are likely to become more consistent as demand for them increases and supplies become more widely available. Growers should try to determine the composition of key fertilizer materials and keep records of their variations over time. It may be worthwhile to send samples of the fertilizers to an independent laboratory for analysis.

The transitional period for new organic operations can be the most demanding in terms of soil fertility management. This is because the benefits of soil building and soil organic matter improvement have not yet been realized in a transitional field, but the grower is limited to only a few soluble fertilizer materials. Growers gain experience during the transitional period, and as the soil organic matter builds, its benefits are reflected in improved fertility management. Materials lists have been developed by the California Department of Food and Agriculture Organic Program and independent certifying agencies and include a broad range of materials to supplement crop nutritional needs. Materials from organic or natural sources may contain dangerous levels of contaminants such as salts, heavy

metals, and boron that may accumulate to toxic levels on a given field. Be sure to pick carefully from the materials available; know the material's source and know its composition.

#### **OTHER PUBLICATIONS IN THIS SERIES**

*Organic Certification, Farm Production Planning, and Marketing,*  
UC ANR Publication 7247

*Soil Management and Soil Quality for Organic Crops,*  
UC ANR Publication 7248

*Weed Management for Organic Crops,*  
UC ANR Publication 7250

*Insect Pest Management for Organic Crops,*  
UC ANR Publication 7251

*Plant Disease Management for Organic Crops,*  
UC ANR Publication 7252

#### **RESOURCES**

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Wyman, C., E. Chapman, and C. Sanders. 1990. *Organic farming directory (revised).* Oakland: University of California, Division of Agriculture and Natural Resources. Publication 21479.

An electronic version of this publication is available on the University of California ANR Communication Services website at <http://anrcatalog.ucdavis.edu>.

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