Nutrient Management for Fruit & Vegetable Crop Production

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MAINTAINING SOIL FERTILITY IN AN ORGANIC SYSTEM

Increased interest in organic crop production has been prompted by both consumer demand and the desire to sustain or improve the soil resource. One of the many fundamental goals of organic farming is to produce a crop with minimal synthetic inputs. The main concept behind this approach is to conserve natural resources by relying more on biological processes within the soil system to recycle and release nutrients rather than provide high amounts of soluble nutrients from manufactured fertilizers. The emphasis is on nutrient cycling within the soil organic matter fraction and enhancement of biological processes to make nutrients within this fraction available to plant roots. The focus of this discussion is to provide information on various approaches to managing and maintaining soil fertility for organic crop production.

Background

When any crop is sold, nutrients are lost from the farm. While many soils can supply nutrients for crop growth without fertilizer additions for many years, eventually the productivity of the farm will decrease unless the nutrients are replaced. A major challenge of managing soil fertility for organic food production is to integrate the input of nutrients from acceptable sources with the use of proper crop rotation. For animal farming operations, this task is fairly straightforward. Farmers will grow and purchase feed for their operation, provide this feed to their animals, collect/compost the manure from the animals, and then apply the manure to appropriate crops. Legumes in association with nitrogen (N) fixing bacteria are used in the rotation to biologically fix N from the atmosphere. These legumes can be used as feed for ruminant animals or as green manure. Deep-rooted legumes also can cycle nutrients from the subsoil to the soil surface. Grasses can also be used as forage and green manure crops to add organic matter and cycle nutrients from lower soil depths. Additional green manure crops include small grains like winter rye, sorghum-sudangrass, and buckwheat.

If livestock are not raised on a farm, nutrients from manure or other organic amendments/fertilizers need to be obtained externally. These organic fertilizers usually have a higher cost per unit of nutrient than synthetic fertilizer sources, which in turn will necessitate obtaining a higher price for the crop unless costs can be cut from other sectors of the operation. Legumes and other green manure crops can still be grown, although it may be more difficult to find room in the rotation if you do not have animals to feed. Forages can be grown as cash crops, but when sold off the farm large amounts of nutrients are exported and must be replaced. Organic crop producers must be creative in finding opportunities in their rotations to grow soil-building legumes and other green manure/cover crops. They need to carefully evaluate the cost of purchasing organic nutrient sources vs. the lost income from growing a non-cash crop.

Nutrient Forms Taken Up by Plants

Before discussing how to manage soil fertility using organic techniques, a simple review of the forms of nutrients that plant roots absorb may be useful. The majority of nutrients must be dissolved in the soil solution before plant roots can take them up. If a fertilizer is applied to the soil, it must first be broken down to its simplest inorganic forms to be efficiently used by plants. Plant roots can absorb some larger organic molecules, but their rate of absorption is slow. From a plant root perspective, it makes little difference if the nutrient originally came from an organic or inorganic fertilizer.

Characteristics of Organic Fertilizers and Soil Amendments

For a fertilizer/amendment to be considered acceptable for organic crop production, certain requirements must be met. From a strict chemical sense, organic means any substance containing carbon. Organic farming, however, does not rigidly adhere to this definition. Some carbon containing fertilizers such as synthetic urea are not acceptable for organic production. Similarly, some materials that are considered to be inorganic (no carbon) such as rock phosphate are acceptable. In general, fertilizers or amendments for organic production must come from natural carbon containing, non-synthetic materials (e.g. manure) or non-synthetic inorganic materials that have not been chemically processed (e.g. limestone, rock phosphate). National standards for organic crop production have recently been adopted (USDA National Organic Program: www.ams.usda.gov/nop). If you are unsure about a particular product, check with the Minnesota Department of Agriculture (http://www.mda.state.mn.us/esap/organic/) or a certifying group like the Organic Crop Improvement Association (http://www.ocia.org/) about its suitability for organic farming before applying it to your field.

Fertilizers acceptable for organic production usually have a low nutrient analysis and are made up of larger, insoluble molecules that take time to be broken down into forms useable by the plant. The composition of fertilizers acceptable for producing organically grown crops varies considerably with moisture content and production practices. A chemical analysis of the organic fertilizer or amendment is necessary to determine precise application rates. Any fertilizer sold commercially (organic or inorganic) must, by law, have the N-P_2O_5-K_2O (nitrogen-phosphatepotash) analysis on the bag. Do not purchase any fertilizer material or soil amendment unless the nutrient content is known. Table 1 provides the approximate nutrient composition of some commonly used organic fertilizers and soil amendments.

Because of their low nutrient analysis, fertilizers used for organic production need to be applied in larger quantities than conventional fertilizers to obtain the same nutrient value. In addition, fertilizers for organic production are only slowly available to the plant. The reason for using these types of fertilizers is that they do not drastically alter soil chemical properties over the short term and that they promote a buildup of organic matter, thereby improving soil physical properties. They usually have a low salt index and, therefore, larger amounts can be applied at one time without causing injury to plant roots. For organic N sources, a single application can be made without having to be concerned about losing most of the N to leaching in a large rainfall event. It is important to point out, however, that excessive applications and misuse of fertilizers suitable for organic production can still cause environmental problems, such as nitrate leaching and phosphate enrichment of surface water. Soil testing, therefore, plays an important role in organic crop production, just as it does in conventional production.

Table 1. Approximate Nutrient Composition of Various Organic Fertilizers and Soil Amendments.

	N	**P_2O_5**	**K_2O**
	-------------------- % (dry weight basis) --------------------		
Dairy manure	2.1	3.2	3.0
Beef manure	1.2	2.0	2.1
Poultry manure	3.0	5.0	2.0
Composted yard waste	1.3	0.4	0.4
Animal tankage (dry)	7.0	10.2	1.5
Alfalfa hay	2.5	0.5	2.5
Blood meal	13.0	2.0	1.0
Fish meal	10.0	6.0	0
Kelp/seaweed	1.5	1.0	4.9
Soybean meal	7.0	1.2	2.0
Bone meal (raw)	3.0	22.0	0
Bone meal (steamed)	1.0	15.0	0
Cottonseed meal	6.0	3.0	1.5
Wood ashes	0	2.0	6.0

Rock phosphate (total P_2O_5)	0	20-32	0
Colloidal phosphate (total P_2O_5)	0	25	0
Greensand (total P_2O_5 and K_2O)	0	1.3	4-9.5
Granite dust (total P_2O_5 and K_2O)	0	0	3-5
Sul-Po-Mag (langbeinite)	0	0	22
Potassium sulfate	0	0	50

Deciding What Amendments Are Needed

For any crop production operation (conventional or organic), decisions on what amendments to apply should be based on a soil test. A soil test should include pH, organic matter content, plant-available phosphorus (P), and available potassium (K) at a minimum. The soil test for nitrate is used in western Minnesota, and in other parts of the state under certain conditions, to adjust N inputs. After a soil test is taken, adjust nutrient inputs based on test results and the crop to be grown. General recommendations for the amount of nutrients to apply based on the crop grown are provided with a soil test. Refer to the University of Minnesota Extension bulletin *Nutrient Management for Commercial Fruit & Vegetable Crops in Minnesota* (BU-5886) for additional information on soil sampling, soil testing, and lime and fertilizer recommendations based on soil test results.

pH Management

The optimum pH for the growth of most crops is about 6 to 7. Soil pH affects both nutrient availability and microbial activity. At pH levels less than 5.5, availability of N, P, K, calcium (Ca), magnesium (Mg), sulfur (S), and molybdenum (Mo) is reduced. In addition, pH levels less than 5.5 reduce the activity of important microbial decomposers, which will greatly depress the biological conversion of organic material to useable nutrients for plant growth. N fixation by legumes is also reduced in these lower pH soils. Over time, soils will tend to become acid with manure applications. Therefore, it is important to monitor pH and apply agricultural limestone according to soil test recommendations if the pH falls below 6.0. Wood ash can also be used to raise pH in an organic system. Wood ash also supplies K, but do not apply it as a K source if the pH is already high. Soils with a pH between 7 and 8.3 are in a range that will promote microbial activity, but may limit P, iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) availability. Use of organic matter amendments and organic foliar products will help increase availability of these nutrients under alkaline conditions.

For acid loving plants such as blueberries, acidifying amendments are often required to reduce soil pH to the range of about 4.5 to 5.2. Elemental S is a suitable acidifying soil amendment for organic systems, as long as the naturally mined mineral has not been chemically altered. Acid sphagnum peat is an organic amendment that can also be used to modify the soil and lower pH, although there is some concern about the sustainability of the widespread use of sphagnum peat. In situations where peat is added to soil to improve soil tilth and water-holding capacity, you should be aware of its acidifying effect and monitor pH to keep it in the desirable range for the plants you are growing.

Nitrogen Management

Of all the essential nutrients, N is the one that is usually most limiting for non-legume crop production and N is often the most difficult nutrient to manage in an organic system. The most common source of N for organic crop production is manure. Many different types of manure are available. The nutrient content of these manures will vary with the animal, bedding, storage, and handling. Although tables are available that have general analyses of manure nutrient content, the recommended method for determining how much manure to apply is to have it tested for nutrient content. Composted manure is the preferred manure source for organic production. Some restrictions apply to use of non-composted manure for organic certification. Refer to the discussion below and check with the Minnesota Department of Agriculture (http://www.mda.state.mn.us/esap/organic/) or a certifying group like the Organic Crop Improvement Association (http://www.ocia.org/) about recommended practices for using manure in organic cropping systems. For further information on nutrient content, nutrient availability, and calculation of application rates for efficient use of manure and compost as sources of plant nutrients, refer to University of Minnesota Extension Bulletin *"Using Manure and Compost as Nutrient Sources for Vegetable Crops"* (M1192).

Fresh vs. composted manure. Fresh, non-composted manure will generally have a higher N content than composted manure. However, the use of composted manure will contribute more to the organic matter content of the soil. Fresh manure is high in soluble forms of N, which can lead to salt build-up and leaching losses if over applied. Fresh manure may contain high amounts of viable weed seeds, which can lead to weed problems. In addition, various pathogens such as *E. coli* may be present in fresh manure and can cause illness to individuals eating fresh produce unless proper precautions are taken.

The National Organic Standards Final Rule (USDA National Organic Program, see pages 45-46 and section 205.203) states that "Raw animal manure must either be composted, applied to land used for a crop not intended for human consumption, or incorporated into the soil at least 90 days before harvesting an edible product that does not come into contact with the soil or soil particles and at least 120 days before harvesting an edible product that does come into contact with the soil or soil particles. Composted plant or animal materials must be produced through a process that establishes an initial carbon-to-nitrogen (C:N) ratio of between 25:1 and 40:1 and achieves a temperature between 131°F and 170°F. Composting operations that utilize an in-vessel or static aerated pile system must maintain a temperature within that range for a minimum of 3 days. Composting operations that utilize a windrow composting system must maintain a temperature within that range for a minimum of 15 days, during which time the materials must be turned 5 times." All manure and compost sources and management techniques must be clearly documented as part of the certification process.

Heat generated during the composting process will kill most weed seeds and pathogens. The microbially mediated composting process will lower the amount of soluble N forms by stabilizing the N in larger organic, humus-like compounds. A disadvantage of composting is that some of the ammonia-N will be lost as a gas. Compost alone also may not be able to supply adequate available nutrients, particularly N, during rapid growth phases of crops with high nutrient demands. The decision on what form of manure to use will ultimately depend on certification requirements, availability, and cost. Composted manure is usually more expensive than fresh or partially aged manure.

Heat-dried manure/compost. Drying manure or compost to low moisture content reduces their volume and weight, which lowers transportation costs, but it also requires energy inputs. Dried products can be easier to handle and apply uniformly to fields, especially those that have been processed into pellets. Heat drying also reduces pathogens if temperatures exceed 150 to 175°F for at least one hour and water content is reduced to 10 to 12% or less. The significant energy costs to heat-dry manure or compost at high temperatures are in contrast to the self-heating generated by microbial respiration during the composting process. Heat-dried composts vary widely in the degree to which they are composted before drying. Many are only partially composted and have higher amounts of soluble (inorganic) N forms than mature, stable compost. This readily available N gives these products some characteristics that are similar to soluble N fertilizers, such as ammonium nitrate. Heat drying of manure and immature compost may increase volatilization of ammonia-N and reduce the total N content of the finished product. In addition, composted or partially composted material that is dried at high temperature rather than going through a curing phase at ambient temperatures is not as biologically active as mature compost. The disease suppressive properties of some composts depends upon recolonization of the compost by disease suppressing organisms during the curing phase. Before using a heat-dried manure/compost product, check to make sure it is certified for organic crop production.

N availability from manure and compost. Bedding or litter will usually decrease the nutrient content of manure by dilution. If materials high in carbon (C) like straw or wood shavings are used as bedding, N availability may be reduced by the larger C/N ratio of the product. High C relative to N will lead to a tie-up of N, potentially causing N deficiency in the crop (see *N Deficiency of Pea Induced by High C/N Ratio* and *N Deficiency of Cucumber Induced by High C/N Ratio*) ***(need to make links to these pictures)***. A C/N ratio of 25/1 or greater will lead to N tie-up in the soil. A C/N ratio of less than 25/1 will release N to the crop. The C/N ratio is also an important consideration in the use of various composts, as well as a controlling factor in the composting process itself.

The N in manure or compost will not all be available to the crop the first year. In non-composted manure, some of the N will be lost to the atmosphere during application in the form of ammonia gas. Manure applied to land should be incorporated as soon as possible after application to avoid ammonia losses. Because the N is stabilized in organic compounds, atmospheric losses of ammonia are not as critical in compost applications, although incorporation is highly recommended. N in the organic form will need to be broken down by microorganisms before plants can use it. The release of N from manure or compost will depend on the type and age of the manure. Anywhere from 5 to 90 percent of the organic N can be released to useable forms the first year. For dairy manure, 40 to 60 percent of the N is generally considered to be available the first year, and 30 to 40 percent of the N is available the second and third years. For poultry manure 50 to 75 percent of the N is available the first year and 20 to 25 percent is available the second and third years. For composted dairy manure, 5 to 20 percent of the N is available the first year.

The residual effects of manure and compost are important. Some benefit will be obtained in the second and third year following application. When manure and compost are used to fertilize crops, soil organic matter will increase over time and subsequent rates of application can generally be reduced because of increased nutrient cycling. Continuous use of manure or compost can lead to high levels of residual N and other nutrients, which can potentially runoff or pollute the groundwater. Taking into account residual release of N in subsequent years should help to avoid excessive applications. Remember that some manure and composts contain high levels of P, so if they are regularly applied to meet crop N demands, soil levels of P can build up to excessively high amounts. Use of soil and tissue tests, and monitoring of crop growth, will help in determining the amount of residual N, P, and other nutrients in the soil and the need for further applications.

Green manures/cover crops. Crops that are incorporated into the soil while still green are referred to as green manures. Cover crops are similar to green manures, but are usually grown to protect soil from erosion during the non-growing season. Because topsoil is higher in organic matter and nutrient content than subsoil, controlling erosion is an important method of conserving soil nutrients. Green manures and cover crops are both used to supply N and increase soil organic matter. Legumes such as clover and alfalfa can fix between 100 and 200 lbs of N per acre in one year. The use of grasses such as rye or oats without a legume will not increase the N content of the soil. These crops are used for increasing soil organic matter content. They can also scavenge residual N from the previous crop and keep it from being lost by leaching. A mixture of both grasses and legumes can be used to obtain the advantages of each. Improved soil tilth from added organic matter improves root growth, which increases the capacity of a crop to take up available soil nutrients. The decision to plant a green manure should take into account the cost of cultural practices (planting, cultivation) and seed, as well as the lost opportunity cost if the green manure is grown instead of a cash crop.

Some green manure crops accumulate high levels of P and are thought to increase P availability to subsequent crops by returning it to the soil in organic form. For example, buckwheat and oilseed radish may solubilize P from relatively insoluble minerals like rock phosphate through the action of organic acids secreted by their roots. The benefit of these P accumulating crops will depend on the following crop and to what extent recycling of organic P increases P availability to them compared to inorganic soil P. There is little research information on P response of different crops following green manures like buckwheat and oilseed radish.

Other sources of N. Sources of N for organic production other than manures and composts include: blood meal, fish emulsion, fish protein, kelp/seaweed, animal tankage, and various vegetable meals. See Table 1 for the approximate nutrient content ($N-P_2O_5-K_2O$) of some of these organic nutrient sources. These materials are usually more expensive than manure or compost and much more expensive than synthetic fertilizers when compared solely on their cost per unit of nutrient. Blood meal is a fast release source of N. Fish emulsion and seaweed can be used as a foliar fertilizer supplements. The low nutrient analysis and high cost of these products usually precludes them from being a primary fertilizer source. Their cost is about 5 to 6 times more expensive (per unit of N) than a conventional inorganic source like urea-ammonium nitrate (28-32% N).

Municipal yard waste and vegetable/plant wastes from grocery stores, vegetable processing plants, and restaurants are other sources of organic material that can be recycled and used for crop production. In most situations these wastes should be composted before use to reduce odors, stabilize the nutrients, and facilitate ease of spreading. Sewage sludge is an organic fertilizer that can supply N and other nutrients, but **sewage sludge is not acceptable** for organic production.

Phosphorus and Potassium Management

The majority (70-90 percent) of P and K in manure will be available to the crop the first year of application. The P and K content of manure will vary with type of manure and storage. Poor storage of manure or compost will lead to losses of K through leaching. Have the product tested for P and K content before application. P sources other than manure for organic production include: bone meal, fish and poultry meal, and rock phosphate. K sources other than manure for organic production include: alfalfa meal, kelp meal, greensand, wood ash, langbeinite (sul-po-mag) and potassium sulfate. See Table 1 for the approximate nutrient content of some of these organically approved nutrient sources. Both P and K are relatively immobile in the soil, so incorporation of P and K fertilizers/amendments to a depth of 6 to 8 inches into the soil before planting is essential to place them in the plant root zone and obtain maximum benefits.

Secondary and Micronutrients

Secondary (Ca, Mg, S) and micronutrient (Fe, Mn, copper, Zn, B, and Mo) needs will be satisfied in most situations through manure, compost, and liming amendments. A major advantage of organic nutrient sources is that they usually contain at least a small amount of all the essential plant nutrients. Deficiencies of some secondary and micronutrients may occur on susceptible crops under certain soil conditions conducive to deficiencies. Use soil tests and foliar tissue analysis to determine whether supplemental applications of these nutrients are needed.

Summary

Practical soil fertility management for organic crop production starts with obtaining a soil test. Amendments added should be based on the soil test results and the requirements of the crop being grown. The nutrient content (at least the major nutrients NPK) of the organic fertilizer or amendment should be known before application. Composted animal manures are the preferred source of organic fertilizer; however, unless an animal operation is nearby or is included on the farm, the expense of these amendments will be much greater than conventional fertilizer sources. These increased costs have to be evaluated by also considering the long-term improvement in soil tilth and biological activity, potential environmental benefits, and the potential for higher returns from organic products.

Websites with Information on Organic Crop Production

1. Organic Production and Certification, Minnesota Department of Agriculture – http://www.mda.state.mn.us/esap/organic/
2. National Organic Program – http://www.ams.usda.gov/nop
3. OMRI (Organic Materials Review Institute) – http://www.omri.org/
4. Organic Farming Research Foundation – http://www.ofrf.org
5. Organic Trade Association – http://www.ota.com
6. Organic Research – http://www.organic-research.com/
7. Organic Alliance – http://www.organic.org/
8. OCIA - (Organic Crop Improvement Association) – http://www.ocia.org/

9. IFOAM (International Federation of Organic Agriculture Movements) – http://www.ifoam.org/

10. The Rodale Institute – http://www.rodaleinstitute.org/

11. All Organic Links – http://www.allorganiclinks.com/

12. Organic Consumers Association – http://www.organicconsumers.org/

13. Canadian Organic Growers – http://www.cog.ca/

14. Organic Farming and Marketing – http://www.ers.usda.gov/briefing/Organic/

15. Organic Agriculture Information – http://www.organicaginfo.org/

16. Alternative Farming Systems Information Center – http://www.nal.usda.gov/afsic/

17. Sustainable Agriculture Network – http://www.sare.org/

18. ATTRA (Appropriate Technology Transfer for Rural Areas) – http://attra.ncat.org/

19. Soil Quality Institute – http://soils.usda.gov/sqi/

20. Sustainable Farming Connection – http://www.ibiblio.org/farming-connection/

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