**Soil Management on Organic Farms**

Managing Soil Fertility in Organic Systems

Managing soil fertility in organic farming systems requires a different approach from that used in conventional farming systems. Nutrients in synthetic fertilizers are highly soluble, so nutrient availability is quite predictable and nutrients are quickly available to plants. They do not require biological processes to make them available. And they do not enhance the biological health of the soil. In fact, several synthetic fertilizers degrade soil by drying it out or making it acidic or saline. Practices and inputs used by organic producers (as well as many others in sustainable agriculture) promote biologically healthy soils that sustain fertility in ways different from conventional systems. They promote the decomposition of plant and animal residues to make nutrients from them available to plants. Managing soil fertility with biologically-created inputs ensures that organic production is a dynamic biological process. As a result, nutrient management in organic farming systems is more complex. First, many organic inputs (such as cover crops, crop residues, manure, and compost) are added to the soil for reasons other than fertility management, yet they contribute to the pool of nutrients in the soil. Second, most organic materials, including compost and manure, have only a small component of soluble nutrients; most of their nutrients must be transformed through biological processes before they become available to plants. Lastly, most manures and composts do not have a consistent nutrient content as found on bags of synthetic fertilizers. They also contain a ratio of nutrients different from that needed for optimal plant growth. In summary, plant-available nutrients in organic systems include **minerals, nutrients that have been mineralized from plant and animal residues, nutrients held in microbial biomass, and nutrients that are being mineralized from decomposing residues.** An organic producer needs to account for each of these nutrient sources to determine current and future nutrient availability as well as view nutrient management as one component of an integrated crop and soil management plan.

**Nitrogen Management**

Nitrogen is often the most limiting nutrient to efficient and profitable organic crop production. Organic growers are limited to organic sources of nitrogen or those derived from natural processes. Soil organic matter is the backbone of nitrogen supply in organic production, and cultural practices to manipulate nitrogen start with building soil organic matter. Other important potential sources of nitrogen include fixed nitrogen from legumes included as a cover or rotation crop, compost produced from on-farm or off-farm materials (Kitchen waste, sewage sludge, food industry waste), manures from on-farm or off-farm sources, and purchased organic fertilizers.

**Organic Sources of Nitrogen**

On organic farms, the main source of nitrogen is atmospheric nitrogen fixed by legumes. In a well-designed crop rotation, plow-downs of legume green manures and forage legumes can provide all the nitrogen required to grow cash crops. Nitrogen is kept on the farm by recycling of nutrients from manure and the applications of composted manure. Although raw manure contains more available nitrogen than composted manure (nitrogen loss as NO3 & NH3), composted manure is preferred for several reasons (readily available N and other macro and micro nutrients, no net immobilization.)

**Soil Organic Matter and Humus**

Organic growers agree to a soil-building program to maintain or enhance soil organic matter as part of their organic certification requirements, and soil organic matter is one important source of nitrogen for organic production. As previously mentioned, the soil organic matter is divided into active and stable fractions. The stable fraction consists in large part of the humus or heavy fraction and affects overall physical and chemical properties in soil. High C:N ratio crop residues such as straw or corn stalks decompose slowly on incorporation and are more often converted to humus.

**Green manure crops**

Green manure crops refer specifically to cover crops grown to supply nitrogen and increase soil organic matter (See Figure 4.4). Cover crops are similar to green manures, but are usually grown to conserve topsoil, prevent erosion, improve soil structure, increase organic matter, and capture and hold nutrients during the non-growing season. Examples of green manure crops include grass (wheat sp, maize, sorghum, rye grass) mixtures and legume plants. Some of the most commonly used are: annual ryegrass, vetch, clover, peas, winter wheat, and alfalfa for winter season. Legumes such as cowpea, soybeab, sesbania and guar may be grown in summer). As a complement to nitrogen from soil organic matter, a vigorous green manure crop may be the most economical organic source of additional early-season nitrogen for the succeeding crop. In crop production areas with mild climates, green manure crops are widely used in organic farming systems because they grow during the fall, winter, and early spring and can develop substantial biomass.

**Manure:**

Fresh, non-composted manure will generally have higher nitrogen content than composted manure. However, the use of composted manure will contribute more to the organic matter content of the soil. The nitrogen in manure is in two forms: the organic form, which releases slowly; and the inorganic form (ammonium, NH4+ and nitrate, NO3–), which are immediately available while organic nitrogen that is more stable and slowly released.

**Compost:**

The nitrogen content of composts will vary according to the source material and how it is composted. In general, nitrogen in the form of ammonium (NH4+) or nitrate (NO3-) is low in composts. The majority of the nitrogen in finished compost (usually over 90%) has been incorporated into organic compounds that are resistant to decomposition. Mineralization rates from compost application are relatively low, and compost is usually a poor short-term source of nitrogen. Rough estimates are that only about 15 percent of the nitrogen in compost will become available the first year following incorporation.

**Commercial organic fertilizers**

Many types of dry and liquid commercial organic fertilizers are available for use in certified organic crop production. Most of these products are byproducts of fish, livestock, and food and other processing industries. Various single-source and blended organic products are available from different fertilizer suppliers and distributors. Some typical examples of organic fertilizer sources include pelleted poultry manure, seabird guano, pelleted seabird guano, feather meal, and blood meal. Commercial organic nitrogen fertilizers are more concentrated nitrogen sources than compost with improved handling, nitrogen placement, and nitrogen availability. While listed on the National List as a prohibited non-synthetic, sodium nitrate (NaNO3, 16% N) mined from naturally occurring deposits in Chile and Peru can be used in organic production in accordance with its annotation.

**Nitrogen Availability**

The nitrogen concentration and resulting C:N ratio of the organic materials will affect whether a net release of nitrogen from the organic material will occur during decomposition, known as net nitrogen mineralization, or whether nitrogen from the soil will have to be used up by soil organisms in order to decompose the organic matter, known as net nitrogen immobilization. Soil microbes readily release the excess nitrogen in a plant-available form when organic matter has a low C:N ratio or when nitrogen is in excess.

**Nitrogen Synchronization**

Synchronizing nitrogen mineralization from soil organic matter, green manure crop residues, and organic amendments to maintain adequate nitrogen availability for crop production is challenging. The rate of nitrogen mineralization from soil organic matter and recently incorporated residues and amendments typically peaks before the crop reaches its maximum rate of nitrogen uptake.

**Phosphorus Management**

Organic crop production systems seek to improve soil organic matter and biological diversity, which may impact phosphorus cycling and phosphorus uptake by crops. Increases in organic matter will be accompanied by an increase in the organic phosphorus pool. Furthermore, management of green manure crops can increase the availability of soil phosphorus pool (both organic and inorganic) by stimulating microbial activity and release of root exudates.

**Organic Sources of Phosphorus**

Phosphorus sources approved for use in organic agriculture have diverse properties that affect phosphorus availability and management. Common phosphorus sources include soil organic matter, green manure crops, manure, compost, and rock phosphate, all of which are frequently used in growing crops.

**Soil Organic Matter and Humus**

Soil organic matter can be an important source of phosphorus for crops. Soil organic matter contains a variety of organic phosphorus compounds, such as inositol phosphate, nucleic acid, and phospholipid. These compounds must be first converted (i.e., mineralized) to inorganic phosphate by soil enzymes before being used for plant growth. These phosphatase enzymes are produced by soil microorganisms, mycorrhizal fungi, or excreted by the plant root.

**Green Manure Crops**

Some green manure crops accumulate high levels of phosphorus and are thought to increase phosphorus availability to subsequent crops by returning it to the soil in organic form. Some green manure crops can be excellent hosts for mycorrhizal fungi, which may allow a greater exploitation of the soil phosphorus reserves. In this symbiotic relationship, the plant root provides the energy (carbohydrate) for the fungi in exchange for improved nutrient uptake and other plant root benefits.

**Manure and Compost**

Phosphorus occurs in livestock manure and in a combination of inorganic and organic forms. In general, 45 to 70 percent of manure phosphorus is inorganic. Unlike nitrogen, phosphorus is conserved in the composting process and, depending on the composting process, the water-soluble phosphorus of mature compost may not be different from that of the original manure source. Organic phosphorus constitutes the rest of total phosphorus. Essentially, all inorganic phosphorus is in the orthophosphate form, which is the form taken up by growing plants.

**Colloidal phosphate**

Colloidal phosphate, also called soft rock phosphate, consists of clay particles surrounded by natural phosphate. Total phosphate is around 20 percent and available phosphate about two to three percent. It also contains about 25 percent lime and other trace minerals. Colloidal phosphate is often added directly to livestock manure, where the manure acids dissolve (Humic acids) much of the total phosphate and the phosphate stabilizes the nitrogen in the manure.

**Rock phosphate**

Rock phosphate from apatite ore has not been acidulated or otherwise chemically treated. Rock phosphates are usually derived from ancient marine deposits. Synthetic fertilizers such as super- or triple superphosphate are made by reaction with sulfuric or phosphoric acid to increase the solubility of the phosphorus in rock phosphates. Organic farming, which does not permit the use of such acidulation phosphate fertilizers, seeks to convert the phosphorus in rock phosphate to crop-available forms by using soil biological processes and natural soil weathering.

**Bone Meal**:

Bone meal, prepared by grinding animal bones, is one of the earliest phosphorus sources used in agriculture. Most commercially available bone meal is “steamed” to remove any raw animal tissue. The primary phosphorus mineral in bone material is “calcium-deficient hydroxylapatite,” which is more soluble than rock phosphate, but much less soluble than conventional phosphorus fertilizers.

**Guano:**

Guano is most commonly used as a source of nitrogen for plants, but some guano materials are also relatively enriched in phosphorus. Guano is mined from aged deposits of bird or bat excrement in low rainfall environments. The drying and aging process changes the chemistry of the phosphorus compared with fresh manure. Struvite (**magnesium ammonium phosphate**) is a major, phosphorus mineral found in guano, dissolving slowly in soil. The limited supply and high cost of guano generally restricts its use to small-scale applications.

Mycorrhizal Fungi

Mycorrhizae (my-cor-ry-zee) fungi are special soil fungus that forms a symbiotic mutualistic relationship with plant roots. In this association both organisms benefit, the fungus takes over the role of the plant's root hairs and acts as an **extension of the root system.** The fungus receives carbohydrates (sugars) and growth factors from the plant, which in turn receives many benefits, including increased nutrient absorption. When a large, vigorous network of mycorrhizae hyphae is associated with a plant's roots, it exponentially expands the “reach” and surface area of those roots, giving the plant greater access to the nutrients, especially phosphorous and other minor nutrients the soil has to offer. This symbiosis is, of course, great for plants, because the extra nutrients can fuel better growth and increase resistance to drought and disease. The value of mycorrhizal fungi for supplying phosphorus for crops is most apparent in low-phosphorus soils.

**Potassium Management**

Most soils hold large reserves of potassium in the primary and secondary soil minerals, but only a small fraction of the total potassium in soil is immediately available for plant uptake. The potassium in the soil solution and the exchangeable potassium held on the soil colloids are readily available for plant uptake. As the exchangeable potassium is depleted, it can be replenished by the reserves of nonexchangeable potassium, but this is a slow process that is generally not rapid enough to satisfy crop requirements.

Organic Sources of Potassium

Regular applications of soluble potassium, regardless of the source, will increase the concentration of potassium in the soil solution and the proportion of potassium on the cation exchange sites. All of the commonly used soluble potassium sources (including manures, composts, and green manures) contain this nutrient in the simple cationic (K+) form. Most soluble inorganic fertilizers and organic manures are virtually interchangeable as sources of potassium for plant nutrition. When using readily available forms of potassium, the overall goal of replacing the harvested potassium is generally more important than minor differences in the behavior of the potassium source.

**Soil Organic Matter**

Potassium is required by plants in amounts second only to nitrogen. Unlike nitrogen and phosphorus, potassium is not organically combined in soil organic matter. Different potassium-containing minerals, such as **micas and feldspars, therefore, are the principal sources of potassium in soils.**

**Manure and Compost**

Manure and compost are usually very good sources of available potassium. For most manures and composts, it is generally assumed that the potassium is soluble and that these can be applied on an equal basis with fertilizer potassium recommendations. However, overuse of manure or compost can lead to excessive levels of exchangeable potassium that can interfere with the uptake of calcium and magnesium by crops.

**Potassium sulfate**

There are two forms of potassium sulfate on the market. One is derived by reacting sulfuric acid with potassium chloride. It is a good fertilizer, but not acceptable in certified organic production. The other is derived from natural sources and it is allowed for organic crop production.

**Langbeinite**

Langbeinite is listed by the Organic Materials Review Institute (OMRI) as allowable in certified organic production if it is used in the raw, crushed form without any further refinement or purification. Several excellent sources of this approved product are available for use with organic crop production.

**Glauconite**

Glauconite is a clay-type mineral, commonly sold as greensand, which is listed by OMRI (organic material review institute) as allowed for organic production. Total potassium oxide (K2O) content of greensand is around seven percent, but most of the potash is unavailable. The very slow potassium release rate of greensand is touted to minimize the possibility of plant damage by fertilizer “burn,” while the mineral’s moisture retention may aid soil conditioning.

Management of Micronutrients

Micronutrients essential to plants include calcium sulfur, iron, manganese, boron, copper, zinc, molybdenum, and nickel. In a biological active soil with good CEC and balanced pH, micronutrient deficiencies are rare. Micronutrient deficiencies are most common in sandy soils, and in soils with very low levels of organic matter.

Organic Sources of Micronutrients

Cobalt, copper, iron, manganese, molybdenum, selenium, and zinc—can be applied to correct a deficiency provided if they are from sulfate, carbonate, oxide, or silicate sources. Nitrate and chloride forms of these micronutrients are explicitly prohibited. Synthetic soluble sources of boron can also be applied.

Chelating Agents

Chelating agents are compounds to which an element in its ionic form can be attached. Micronutrients can be made more available to plants by chelation with various compounds. Naturally occurring chelating agents such as **citric acid may be used**. Synthetic chelating agents on the National List such as lignosulfonic acid and its salts; and humic acids are more commonly used. Synthetic chelating agents not on the National List such as EDTA and DTPA are prohibited.