Mineral Nutrient Management for Organic Fruit Production

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Organic apple production offers a niche market which may be of interest to some growers. Organic soil management requires a holistic approach to agricultural ecosystem management. Because of the perennial nature of apple orchards, this is not a great departure from conventional orchard management, except that corrective techniques are limited primarily to naturally derived materials.

Many apple growers are currently seeking to increase profitability through market diversification. One way that growers can distinguish their product from others is by describing and promoting the process by which it is produced (O'Rourke, 2002). Examples of "process-driven" market alternatives include Integrated Fruit Production, Integrated Pest Management, Sustainable, Organic, and Biodynamic. The most widespread and established of these is organic production, a label that provides an alternative for affluent socially conscious consumers who prefer fewer chemicals in their food (Fresh Trends, 2002).

Although mineral nutrition is an important component of organic orchard management, there are other factors more critical to the success of an organic orchard. These include: good market demographics, grower commitment, and a workable pest management strategy. Demand for organic produce is higher in metropolitan areas, (especially those with nearby college campuses) than in rural areas (Fresh Trends, 2002). While some consumers are willing to pay a modest premium for organic produce, the extreme complexity of apple pest management with its limited organic management options and higher production costs requires great dedication on the part of the grower. Only growers who are committed to making the system work will remain organic in the long run.

Organic Regulations

Organic production has a regulatory component which typically involves a third-party certification that only approved practices and products were used in the production and handling of the crop. The USDA National Organic Program (NOP) established national standards for organic labeling in 2002, and these regulations are interpreted by accredited state or private certification agencies. The certification agency has the final word on whether the crop can be certified as organically produced. Although the NOP should result in uniform, consistent standards, certification agencies can vary considerably in fees, documentation required, and sometimes the products that are restricted or the practices required. Make sure you have read and understood the criteria for certification, and make sure your intended customer accepts the same practices and products as the certifying agency.

Farms with less than $5000 in annual sales of organic products can be exempted from certification, but still must abide by NOP standards. A person who knowingly sells or labels a product that fails to meet NOP standards as organic can face a civil penalty of up to $10,000.

The Organic Material Review Institute (OMRI) is an organization that evaluates proprietary products to determine if they meet the standards for organic production under the NOP. OMRI lists brand name products, such as blended fertilizers with more than one ingredient. They also provide a "generic materials list" for single-ingredient products, such as ground limestone or peat moss, which can be used regardless of brand name provided the product is pure. Not all manufacturers are willing to pay the fees to have their products listed by OMRI. It is possible that an unlisted product may be organically acceptable, however the grower must determine whether all of the product's ingredients and its manufacturing process are organically acceptable.

Mineral Nutrition and Groundcover Management

Groundcover management and mineral nutrition are integrally linked. While it is beyond the scope of this paper to present an in-depth description of organic groundcover management, some discussion of this topic is necessary to help the reader envision the type of groundcover system into which the mineral nutrient management practices are being integrated.

Orchards are typically planted on slopes where erosion is a concern. A permanent fescue sod between the tree rows will prevent erosion and reduce soil compaction from the operation of farm equipment in the alleys. Hard or red fescues are slow growing, reducing the need for mowing, and are poor alternate hosts for apple pest organisms. Because fescues are slow to establish, it is best to apply the seed at the high end of the recommended seeding rate to establish a full ground cover as rapidly as possible and prevent weeds from becoming reestablished. A seeding mixture of annual rye and fescue is sometimes used to speed the rate of groundcover establishment.

Apple is a weak competitor for water and nutrients. A three- to four- foot-wide weed-free strip under the trees should be maintained to reduce this competition. This is particularly important during the first several seasons of the orchard. Newly transplanted trees have impaired root systems and this further weakens the ability of the trees to compete with weeds. An effective weed management program fosters rapid early tree growth and early fruit production, resulting in a faster return on investment. Weed management is among the biggest challenges in organic apple production (Jim Bittner, Singer Farms, personal communication).

The primary weed control options for organic blocks are cultivation, burning or mulches, and each option has its pros and cons. Cultivation provides immediate and effective weed control, but must be reapplied several times each season, resulting in increased labor and fuel costs (Schupp and McCue, 1996). Long-term use of cultivation reduces soil organic matter. To minimize the negatives, cultivation should be limited to monthly treatments in May, June and July, followed by a cover crop of canola or vetch in late August.

Mulches can provide adequate weed control if renewed every one or two years, but are expensive, and create a favorable habitat for voles. The decomposition of mulches contributes organic matter to the soil in the long term, but ties up mineral nutrients in the short term, especially nitrogen (N). Nitrogen deficiency can contribute to limited tree growth and low productivity. Coarse shredded bark or woodchip mulch will decompose more slowly than finer materials and is less favorable to voles (Merwin, 1995). Bark or woodchip mulch should be supplemented with hand or flame weeding when the trees are young.

Site Selection & Preparation

The primary strategy of organic mineral-nutrient management is building and maintaining a soil that is biologically active and high in organic matter. Orchard sites are typically selected for climatic conditions, slope, elevation, location relative to other producers and markets, and of course, availability of the real estate. Soil characteristics of a prospective orchard site are often a secondary consideration. Selecting an orchard site with good soil properties is essential when planning an organic block.

Modifying soil characteristics is a long-term process and correcting soil problems in an established orchard is difficult. Furthermore, there are few rapid rescue options available to the organic grower. Starting out with soil that has adequate depth, drainage, texture, water and nutrient holding capacity, pH and mineral nutrient content is always advisable, but with organic production, it is vital.

Once an appropriate site has been selected, pre-plant soil preparations to correct any deficiencies, and to increase organic matter and biodiversity of the soil should begin. Ideally one should plan on spending two years on site improvement before planting the orchard.

Soil testing is used to establish the baseline values of soil acidity, organic matter content, nutrient holding capacity, and mineral nutrient content. Liming to increase soil pH and measures to increase organic matter and mineral nutrients are best addressed prior to planting. This way lime and organic matter can be incorporated deeply into the soil with cultivation so that soil properties are optimized throughout the root zone. This is also the time to tile poorly drained parts of the site and eliminate existing weeds.

Lime should be added to raise the soil pH to 6.5. If the soil test indicates a need for magnesium (Mg), dolomitic, or high mag lime should be used. One or two annual applications of 20-25 tons per acre of cow or chicken manure can also be beneficial for increasing organic matter and adding mineral nutrients to the soil. Horse manure should be avoided, as it is low in nutrient value relative to other animal manures. Furthermore, weed seeds often survive the inefficient digestion of a horse's gut and can contribute to the introduction of new weed species.

Animal manure must not be stockpiled prior to use, as it can cause severe problems with neighboring residences due to both odor and flies. Manure should be tilled in promptly after spreading to incorporate it and prevent loss of N due to volatilization. Typically, seeding a green manure or cover crop such as buckwheat or Sudex follows manure applications. These crops are mowed down before going to seed and then tilled down. The manure application and cover crop are repeated, followed by seeding the permanent ground cover in late summer the season before planting.

Pre-plant Compost

Organic matter is often low in many existing orchard soils, and increasing it improves soil water and nutrient holding capacity. This enhances root regeneration and promotes overall tree vigor. Adding compost as a source of organic matter to planting holes has been demonstrated to have beneficial effects on young apple tree growth in experiments in Massachusetts and Maine (Autio, et al., 1991). The effects of planting-hole treatments are most visible during the year of planting. As root growth extends beyond the volume of the planting hole, the effects of planting-hole treatments diminish. If organic matter amendments were broadcast throughout the orchard soil, perhaps the beneficial growth response could be sustained for a longer period.

For pre-plant compost to be a feasible management practice, an economical, local source of compost must be available. University of Maine Cooperative Extension developed an apple pomace composting project in cooperation with Chick Orchards in Monmouth, Maine. Apple pomace from Chick's cider operation was mixed with leaf waste from the local waste transfer station, and chicken manure from a local egg farm at a 2:6:1 ratio by volume. Wood ash was used to adjust the pH to 5.8 prior to composting. Composting reduced the volume of apple pomace waste by 50 percent, and converted it into an organic soil amendment with highly desirable characteristics. A study was initiated in Maine in 1998 to determine if pre-plant incorporated apple compost or synthetic phosphate (P) fertilizer, either alone or in combination, would improve early apple tree growth and precocity.

The results of this study indicated that pre-plant compost incorporation was more effective than P fertilization for increasing tree growth during the establishment years (Schupp and Moran, 2002). Soil-incorporated compost resulted in increased tree growth and flowering into the third year after planting. Greater tree growth with compost was most likely due to improved N and K status of the trees, and through improved soil aeration and water holding capacity. These results suggested that trees planted in soil amended with apple pomace compost would potentially fill their space more quickly and be able to support more fruit growth in the first years of cropping.

Mineral Nutrient Maintenance

Harvesting an apple crop doesn't remove large amounts of minerals from the soil, compared to many crops (Stiles and Reid, 1991). Apple trees are deciduous perennials with mechanisms for remobilizing essential minerals and storing these in the perennial organs prior to leaf abscission in the autumn. The result is a production system that requires relatively modest mineral nutrient inputs to maintain optimal production. Potassium is the one mineral that is removed in significant amounts with the harvested crop and more significant inputs are required.

Selecting soils with good nutrient holding capacity, maintaining optimal soil pH, and maintaining high (3-4%) soil organic matter will result in most of the orchard's nutritional needs being met by natural cycling, provided weed control is adequate to prevent competition. Still, some supplementary fertilizer application is usually necessary to maintain optimal yield and fruit quality.

The primary method of providing both organic matter and mineral nutrients is the application of compost. The availability of mineral nutrients from compost usually occurs at a slower rate than that from inorganic salts. For this reason, compost is often applied after harvest in autumn or at bud break in early spring. The compost application rate is often based upon the amount of available N relative to that required by the block. For example, if one were applying compost with 5 percent N to an orchard requiring 40 lb actual N per acre, the rate of compost would be 800 lb. By comparison the rate of compost with two percent N for the same block would be 2000 lb per acre.

Composts can vary greatly by ingredients, nutrient value and cost. Make sure you select composts that originated from approvable ingredients and processes; they should be ones that provide adequate amounts of the nutrients needed, and that provide good value relative to the cost. One way to reduce both the purchase price and transportation cost of compost is to use farm waste to produce you own. Apple pomace is one potential source of high carbon waste available to many apple growers, and can be combined with other ingredients to produce high quality compost, as previously described. See Edwards (1998) for detailed information about on-farm composting.

Under NOP regulations, products - including fertilizers- are listed as "allowed" or "not allowed," "not prohibited" or "prohibited." Only those materials that are listed "allowed" and "not prohibited" may be used on organic crops. In some cases the origin of a substance affects its status. Gypsum from a mined source is non-synthetic and is not prohibited, while gypsum by-products, such as scrapped dry wall is synthetic and not allowed. Always check with the certifying agency to make sure that the products you intend to use comply with organic standards.

Adequate mineral nutrients must be available in order for the trees to assimilate large amounts of carbon, partition those assimilates into fruits, and then for those fruits to maintain premium eating quality until consumed. Organic nutrient sources are lower in nutrient concentration and generally more complex than non-organic salts. Organically derived nutrients may not be readily available until decomposition. This slower process requires management with a long-term perspective.

Tracking the trends in mineral nutrient levels in annual leaf samples over several years is the single best way to monitor orchard fertilizer needs. The annual leaf sample should be supplemented with a soil sample every third year. Steps can then be taken to begin corrective measures when a macronutrient shows a trend toward becoming sub-optimal, rather than waiting for an actual shortage to develop. Conversely, foliar sprays of micronutrient fertilizers are permitted under NOP guidelines only when there is a documented shortage. In either case, leaf analysis is necessary to assess the situation.

The principal nutrient required to maintain adequate tree vigor and productivity is N. Organic N sources include manure, fish emulsion/meal, bone meal and blood meal.

Animal manures should be applied pre-bloom in most cases, as NOP regulations prohibit use of animal manures within 90 days of harvest to prevent possible *E. coli* contamination of the crop. Manures can provide higher concentrations of mineral nutrients, especially N, compared to compost; however much of the N value of manure can be lost to volatilization unless it is soil incorporated. For this reason, manures are better suited to groundcover management systems utilizing cultivation.

Matching nutrient needs with those provided by alternative sources allows the grower to provide the best fit of nutrient supplements. Manures provide multiple nutrients besides N. Chicken manure for example is high in phosphorous.

Fertilizers containing soluble forms are more expensive, but are more quickly available, thus they are useful for correcting a deficiency. Sodium nitrate (Chilean nitrate) is listed as not prohibited as long as use is restricted to no more than 20 percent of the crop's total N requirement. Organic standards in the UK prohibit the use of blood and bone meals, so these N sources should not be used on fruit grown for export.

Harvest removes 60-100 lb per acre of potassium (K) annually, while most orchard soils in the northeastern U.S are naturally low in potassium and magnesium (Mg) (Stiles and Reid, 1991). Compost can provide meaningful amounts of these minerals (Schupp and Moran, 2002). In addition to organically derived sources, Sulpomag, a mined material, is frequently used as a source of both K and Mg. Magnesium sulfate (Epsom salts) is allowed as a soil amendment if there is a documented soil Mg deficiency.

Ca deficiency is often associated with low soil pH. Lime is the primary material for maintaining soil Ca. Mined gypsum may be applied when it is desired to increase soil Ca without raising pH.

Bitter pit is an apple disorder associated with low fruit Ca (see the preceding article by Watkins, et al.). Nutritional imbalances such as excessive N, K, or Mg, and deficient B, as well as non-nutritional factors, such as variety, excessive fruit size/low crop load, or drought can contribute to low fruit Ca, even when soil Ca is adequate. In such instances, foliar sprays of calcium chloride ($CaCl_2$) are permitted to reduce the incidence of bitter pit. Under NOP regulations, the $CaCl_2$ used in organic orchards must be extracted from brine.

Deficiencies of boron and other micronutrients may be corrected using synthetic foliar fertilizers, if a deficiency is documented by soil or leaf analysis. In general, micronutrient chelates and sulfates are allowed. Those made from nitrates or chlorides are not allowed.

Summary

Organic production requires a holistic approach to agricultural ecosystem management. Because of the perennial nature of apple orchards, this is not a great departure from conventional orchard management, except that corrective techniques are limited primarily to

TABLE 1

Information Resources for Organic Apple Production

Organic Certification:

National Organic Program (NOP): http://www.ams.usda.gov/nop/
Organic Material Review Institute: http://www.omri.org/crops_generic.pdf

Organic Apple Production Manuals:

Edwards, Linda. 1998. Organic Tree Fruit Management. Certified Organic Associations of British Columbia, Keremeos, BC, Canada. ISBN 0-7726-3615-X
Swezy, S.L., P. Vossen, J. Caprile, and W. Bentley. 2000. Organic Apple Production Manual. Univ. Calif. Agric. and Nat. Resources Publ. 3403. Univ. Calif. Agric. and Nat. Resources Commun. Serv., Oakland, CA. ISBN 1-879906-48-1

Organic Apple Web Sites:

http://www.attra.org/attra-pub/apple.html
http://www.attra.org/attra-pub/fruitover.html
http://www.attra.org/attra-pub/ipm.html
http://www.caf.wvu.edu/kearneysville/organic-apple.html
http://www.canr.msu.edu/vanburen/appleweb.htm
http://www.canr.msu.edu/vanburen/organasp.htm
http://orchard.uvm.edu/uvmapple/pest/#Organic Pest Management

naturally derived materials. It is very challenging to produce apples organically, because of the need to maintain the planting over many years without rotation, the vast pest complex, and the exacting demand for high quality, unblemished fruit in the fresh apple market, where much of the growth potential for organic fruit lies.

Organic mineral nutrition management hinges on two principals: 1) practices that lead to the buildup and maintenance of soil that is biologically active and high in organic matter; and 2) supplementing the mineral nutrients provided by the soil with fertilizers from approved sources. Organic orchards should be sited on land with superior soils and pre-plant soil preparation to increase organic matter and correct any sub-optimal soil characteristics. Weed management is critical to reduce competition for nutrients and water.

Soil and leaf analysis provide the basis for correcting mineral nutrient deficiencies or imbalances, and with organic production, changes should be tracked over several years. It may be necessary to use a number of strategies to supply mineral nutrients over the life of the orchard. The slower, natural methods require a management approach that is simultaneously patient and dynamic. The organic approach may increase crop value, however as with most premium market niches, the value is balanced with higher production costs and more management inputs. Personal satisfaction has to be considered part of the reward in order to sustain the energy required to manage an organic orchard.

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The figure below is a correction for the figure which appeared on page 11 in the article **"Adjusting Soil pH for Optimum Nutrient Availability"** written by Lailiang Cheng and Warren Stiles, Department of Horticulture, Cornell University, Ithaca, NY.

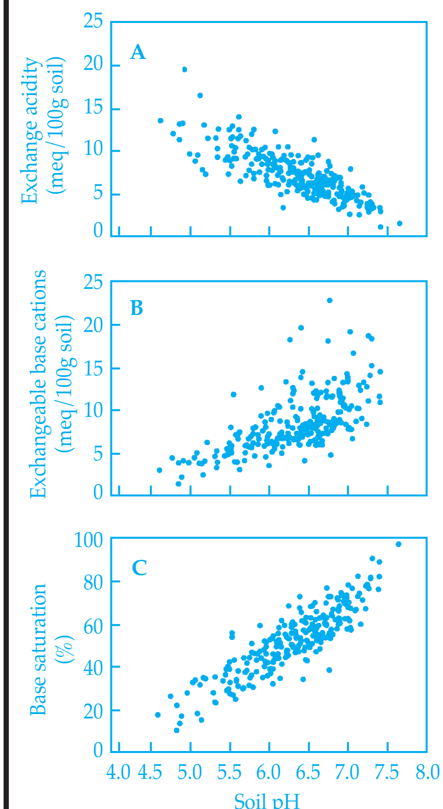

Figure 1. Exchange acidity (A), exchangeable base cations (B), and base saturation (C) in relaiton to soil pH in 250 Hilton soil samples from Western New York apple orchards.