Practical Nutrient Management for Organic Vegetable Crops

or how to stay in business while caring for the soil as a living system

Mark Schonbeck, Virginia Association for Biological Farming

This handout was prepared for the 2012 Grower's Academy, a series of courses specifically designed to help new and transitioning vegetable and cut-flower businesses succeed. Now in its third year, Grower's Academy is the result of a partnership between VT EarthWorks and Virginia Cooperative Extension.

One of the biggest challenges facing new or transitioning organic farmers, and agricultural professionals working with them, is determining appropriate organic fertilizer and other inputs based on a standard soil test. Fertilizer recommendations provided with soil test reports are based on research into yield responses to nutrient applications on conventionally managed soils. Thus, one of the most frequently asked questions is: "How do I translate this into 'organic'?"

Nutrient management in organic systems differs from conventional in three ways. First, conventional fertilizers become available immediately (e.g., ammonium nitrate, potassium chloride), or over a fairly short and predictable time span (e.g. superphosphates, urea). In contrast, most organic sources of fertility release nutrients more slowly, and the rate of release depends on soil temperature, moisture, and biological activity. Second, organic and conventional nutrient management approaches are based on different assumptions regarding the nature of soils and the role of soil life in modulating availability of crop nutrients. Third, crop nutrients (whether from conventional or organic fertilizers, or from soil organic matter) behave differently in soils under long term organic or sustainable management than they do in depleted or conventionally managed soils, or early in the process of converting to more sustainable systems.

Organic nutrient management aims to build a healthy, living soil, in which the action of soil organisms on organic matter releases most of the nutrients required by the current year's crop. A diversity of organic materials, including cover crops, compost, organic mulches, and crop residues, is returned to the soil to feed soil life and replenish nutrients and organic matter removed in harvest. Whereas the vital role of soil life in soil fertility and crop nutrition has gained widespread recognition over the past 15 years, Extension and other agricultural professionals still seek practical tools for making organic fertilizer recommendations that will give reliable results. The truth of the matter is that *there is no definitive formula for translating standard soil test recommendations into "organic."* Yet, experienced organic producers manage nutrients effectively, obtaining yields comparable to conventional agriculture while reducing water pollution with nitrogen (N) and phosphorus (P) (Liebhardt, 2001).

Organic gardeners often say, "feed the soil, and the soil will feed the crop." However, economic reality in a farm enterprise may require a "feed the soil *and* the crop" approach. You may need certain "supplements" to obtain economically satisfactory yields, especially in fields recently converted to organic production. Use cover crops, compost, and organic residues to restore depleted soils, and also NOP-allowed fertilizers and mineral amendments to:

- Address deficiencies in specific crop nutrients.
- Adjust soil pH as needed.
- Replenish depleted soil nutrient reserves.

Once soil quality is restored, and nutrient and pH levels are near optimum, organic fertilizer inputs can be reduced. The farmer then adjusts annual inputs to:

- Replenish nutrients removed in harvest.
- Meet nutrient demands of heavy-feeders (some vegetable crops just have to be "fed").
- Maintain soil life, organic matter, and soil quality.
- Avoid building up nutrient excesses.

Nutrient Dynamics

Plants take up most nutrients, especially nitrogen (N), phosphorus (P), and potassium (K), in soluble mineral forms, including nitrate (NO_3^-), ammonium (NH_4^+), phosphates (e.g., $H_2PO_4^-$), and potassium ion (K+). Soil testing protocols are designed to measure these plant-available forms of NPK.

The bulk of soil N is present in organic form, as an integral part of the soil organic matter (SOM). Soil life mediates N availability to the plant, and is essential for releasing N from the soil organic matter so crop roots can take it up. Because of the environmental, climate, water quality, and human health impacts of nitrate-N leaching and denitrification from fertilized soils, managing N to meet crop needs while avoiding these adverse impacts is a major challenge for both conventional and organic farmers.

Most of the soil P is present as insoluble mineral and organic forms. When readily available fertilizer P is added, a significant fraction of it rapidly becomes "fixed" or immobilized into insoluble mineral or organic forms. Thus, flooding the soil with a large amount of available P at one time (via manure or chemical fertilizer) is not an efficient way to provide for crop P nutrition. On the other hand, soil life, especially the root-symbiotic mycorrhizal fungi, can solubilize organic P and even some of the mineral-fixed P. Good soil biological activity is essential to efficient utilization of P, and to adequate crop P nutrition in sustainable production.

Plant-available soil K is held on the cation exchange capacity (CEC - negatively charged clays and humus). Most soils also have a lot of insoluble K bound up in their mineral fraction. Some soils tend to "fix" K when large amounts of soluble K are applied at once, which can make it difficult to raise available soil test K to optimum levels. However, grasses and trees can unlock some of the mineral-fixed K, and subsequently return it to the soil in more available forms. Building soil organic matter contributes to CEC and helps keep plant-available K on hand.

Secondary and micro-nutrients essential to plants include calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and nickel (Ni). Of these, B is often deficient in southeastern US soils, and deficiencies of Mg, Ca, S, Mn, Cu, and Zn occasionally occur.

Most vegetable crops are heavy nitrogen feeders, requiring 100–200 lb N/ac. Warm-season crops like tomato, sweet corn, or pumpkin absorb N over a fairly long period while the soil is warm. Thus, a fertile, biologically active soil may release sufficient N through mineralization to meet crop needs. However, an early-maturing, cool-season heavy feeder like broccoli or spinach requires a lot of N in a short period of time in spring, while the soil is cool. In this case, the soil life may not mineralize enough N to keep up with crop N demand. An application of a faster-releasing organic N source, such as feather meal, blood meal, or soybean meal, may be needed.

Vegetable crops utilize only about 20 lb P/ac, or 1 lb P (2.3 lb P_2O_5) for every 6–10 lb N. Because readily available fertilizer P tends to become immobilized ("fixed") in insoluble soil minerals, P recommendations often considerably exceed the amounts crops are expected to consume, in order to ensure adequate P nutrition for the crop. With continued heavy annual P applications, the soil's P fixation capacity becomes saturated, and surpluses begin to build up.

Excessive soil P levels pose a threat to water quality and aquatic ecosystems, and also inhibit the growth and activity of the highly beneficial mycorrhizal fungi in the soil and crop roots.

Excess P in runoff has become a major pollutant in waters such as the Chesapeake Bay and the Gulf of Mexico. At the same time, P fertilizer is a limited resource worldwide, and "peak phosphorus" is considered a major threat to global food security. This paradox represents a double imperative to utilize P as efficiently and frugally as practical in crop production.

Vegetable crops use a lot of potassium (K), perhaps 100–300 lb/ac. Some soils, especially those rich in mica clays, can tie up K in insoluble or "mineral-fixed" forms, making it harder for vegetable crops to access the nutrient. Including cereal grains (for harvest or cover crop), perennial grasses, and woody perennials in the cropping system can help unlock the fixed K. Very sandy soils with low SOM have little capacity to hold on to K, and K may be lost to leaching. Efforts to build stable SOM are especially important for K nutrition on these soils. Generally, crop rotation and good soil organic matter management can help maintain crop K nutrition, and reduce the need for expensive NOP-allowed K fertilizers.

Unlike N and P, excess soil K does not pose serious water pollution or other environmental hazards. However, K management merits attention, since K excesses can adversely affect crop nutrition, livestock health, and physical properties (tilth) in soils rich in certain clays.

Causes of Crop Nutrient Deficiencies

Crops can be nutrient deficient for any of several reasons:

- The nutrient is truly lacking or limiting in the soil.
- The soil life is depleted or out of balance.
- The soil is dry or cold, rendering the soil life dormant.
- The soil is compacted, or a subsurface hardpan exists, thereby restricting root growth.
- A highly acid subsoil with little SOM contains toxic amounts of aluminum (Al), which inhibit root growth beyond a certain depth.

Two or more of these conditions often occur together, and need to be addressed in an integrated approach. The first is remedied through the addition of appropriate organic fertilizers or amendments. Soil life is restored by introducing a diversity of beneficial soil life (sources include good compost, worm castings, compost teas, biodynamic preparations, and mycorrhizal and other soil inoculants). Appropriate irrigation, optimum planting dates, and season extension help maintain favorable conditions for soil life as well as the crop. Subsoiling or chisel plowing, followed by deep rooted cover crops can relieve compaction or hardpan. Calcium amendments, especially gypsum (calcium sulfate) reduce solubility and phytotoxicity of subsoil Al.

Goals and Pitfalls in Organic Nutrient Management

Organic farmers use a combination of "feed the soil" and "feed the crop" practices to secure satisfactory economic returns while building and maintaining a high quality soil. Research-based guidelines for nutrient management in sustainable production (Magdoff & van Es, 2009; Peet, 1996) can help in achieving this balance.

Short term organic nutrient management goals include:

- Correct acute soil nutrient deficiencies, and nutrient or pH imbalances.
- Tailor nutrient availability to each crop to maintain profitable yields.
- Restore soil organic matter and soil life.

Longer term goals include:

- Maintain high levels of active organic matter and humus, and a diverse soil biota that provides for most crop nutrient needs.
- Maintain optimum soil nutrient and pH levels.
- Balance nutrient exports (harvest) with nutrient inputs.

Pitfalls in organic nutrient management include insufficient nutrient inputs resulting in low yields or long-term depletion of soil reserves ("soil mining"); and excessive nutrient inputs resulting in potential N and P pollution of nearby water resources, increased pest or weed problems, and unnecessary costs to the farmer. New farmers who interpret organic philosophy as "avoid purchased inputs and let nature take its course," and organic farmers managing larger acreages, tend to underapply nutrients. Farmers and market gardeners with small, intensively managed acreages sometimes overapply nutrients in the belief that "the more compost, aged manure, and organic mulch, the better." In addition, farmers in transition from conventional to organic production of heavy feeding vegetable crops sometimes overcompensate for the slower release of organic nutrient sources to make sure crops are not nutrient limited.

One common pitfall is the use of composted or aged manure to provide most of a crop's N requirements, year after year. Crops consume N and P in a 6:1 ratio or higher, while manure and compost often contain N and P in a 2:1 or 3:1 ratio, with only 25-50% of the N immediately available to the current crop. As a result, using these materials as the primary N source will add several times as much P as the crop will use. If soil P reserves are low, this is a good way to build them up; however once soil P levels reach optimum ranges, manure and compost inputs need to be cut back. Otherwise, P excesses will build up, which can tie up micronutrients, inhibit the growth of the valuable crop-symbiotic mycorrhizal fungi, and pollute nearby waters.

Poultry litter and compost or fertilizers based thereon (such as Harmony™ 5-4-3 N-P_2O_5-K_2O) are especially rich in P. Because crops often respond dramatically to these materials, both conventional and organic farmers often use them regularly. In addition to P, poultry manure-based amendments also contain large amounts of Ca (9% in Harmony 5-4-3), substantial liming (pH-raising) capacity, and significant amounts of the micronutrients Zn and Cu. They can be valuable on soils that are low in these nutrients, but should be avoided or used sparingly if soil pH is near 7 (neutral), or soil test P, Ca, Zn, or Cu is already high.

Because much of the "unavailable" N in compost or manure is added to the soil's mineralizable organic N pool, surpluses of N as well as P may build up if heavy annual inputs are continued. Studies on New York farms have shown that, once soil organic matter, N and P levels are adequate, annual total N and P inputs from organic sources can be budgeted to equal annual N and P removal through harvest, with no loss in yields (Drinkwater, 2003).

Similarly, the heavy use of grass hay mulches year after year can build soil K levels up high enough to upset nutritional balance. One result may be increased incidence of blossom end rot (tomato, pepper, and cucumber)), tip burn (lettuce and other leafy crops) and other physiological disorders related to localized Ca deficiency. Another may be increased problems with certain weeds. In addition, livestock feeding on forage or crop residues that are very rich in K relative to Mg can suffer from grass tetany, a potentially life-threatening condition. Because vegetables are heavy K consumers, K excesses are easier to avoid or to draw down through harvest, than P excesses. In addition, whereas some K may leach from sandy soils low in organic matter, K leaching is not considered a significant threat to water quality or aquatic ecosystems.

Cover crops add organic matter by converting carbon dioxide *in situ* into organic carbon (C), and legumes fix atmospheric N. However cover crops do *not* add more P or K. Thus*, legume cover crops become an important nutrient management tool in organic crop production on soils that already have optimal or excessive P or K levels*. At the same time, on soils with lower levels of these nutrients, cover crops can enhance the availability of soil P (especially legumes and buckwheat) and K (especially cereal grains) to following cash crops.

Some organic farmers seek to "balance" cation nutrients (K, Ca, and Mg) to match base saturation [percentages of soil cation exchange capacity (CEC) occupied by each element] considered optimum for soil and crop health: 3–5% K, 65–70% Ca, and 10–15% Mg. Some may also aim to raise sulfur (S) and other micronutrients to high levels to promote crop pest resistance and "nutrient density." Numerous studies have shown that most crops grow well in a fairly wide range of soil Ca and Mg levels (~50–80% Ca and 10–25% Mg). Most soils in our region have significant S reserves in the subsoil, although crop S deficiency can occur on sandy soils with S test values below 10 ppm. Although using lime, gypsum, and other amendments to achieve "ideal" base saturation percentages and S levels is not harmful to crop, soil, or water quality, it can entail unnecessary costs to the farmer and to the environment (through impacts of mining).

Boron (B) is one essential crop micronutrient that is often deficient in southern US soils. Brassica vegetables, beets, and alfalfa are most susceptible to B deficiency; tomato, spinach, carrot, and other root crops are moderately so. Boron should be applied as needed, broadcast evenly at no more than 1–2 lb elemental B per acre at any one time, to avoid harmful excesses.

Nitrogen Budgeting for Organic Farmers: Slow-release N and C:N ratio

Unlike conventional nutrient management, in which soluble N is applied on a schedule designed to match crop needs, organic N management requires careful consideration of the role of soil life and of carbon to nitrogen (C:N) ratios. When raw organic materials with a C:N ratio of less than 20:1 (such as fresh manure with little or no bedding, or a succulent all-legume green manure like hairy vetch or alfalfa) are added to the soil, soluble N is released fairly rapidly into the soil, from which it can be taken up by growing crops – or lost through leaching, denitrification, or volatilization, similar to conventional N fertilizers. Organic materials with a C:N ratio of about 25:1 release N slowly while decomposing, whereas materials with C:N ratios above 35:1 (such as a mature rye cover crop, tree leaves, or straw) can immobilize (tie up) soil N for several weeks or months. The soil food web generates the most active organic matter and stable humus from organic residues with C:N ratios of 25-35:1. A grass-legume cover crop biculture, grown to early flowering, usually has a C:N ratio in this optimum range.

Because biological processes regulate N release from organic materials, organic farmers need a different approach to N budgeting from the formulaic "X pounds of N per acre for Y bushels-per-acre crop" of conventional production. Any farmer who uses manure or cover crops can and should calculate "N credits" from these sources to save on N fertilizer bills and protect water resources. Furthermore, in biologically active soils, the SOM itself is a significant N source for the current crop. Cornell University estimates 20 lb/ac N released per 1% SOM content per year, while some private soil testing labs such as A&L Eastern Labs in Richmond, VA calculate an "estimated nitrogen release" (ENR) based on %OM, CEC and soil texture. In our warmer climates, a sandy soil with 2.5% OM or a clay-loam with 4% OM may release about 100 lb N/ac annually, which is over half the N requirement of most vegetable crops. *Replenishing this OM-derived N through legume cover crops and organic inputs is vital for long term sustainability.*

The percent of total N that is available to the current year's crop can be estimated at 50% for manure and most cover crops, and just 10-25% for compost. Most of the rest of the compost N, as well as N in a grass-legume green manure, becomes incorporated into the soil organic N pool, thus helping to replenish this vital long-term source of N. Some manure N may leach or volatilize, and some may enter the organic N pool, depending on the C:N ratio of the manure-bedding mix. While the "available" portion of compost, manure, and cover crop N help provide for the needs of the current crop, the "unavailable" portion of compost and cover crop N, and at least part of unavailable manure N go toward replenishing soil organic N.

How to Read a Soil Test Report

Standard soil test reports obtained through land grant university Extension services, state departments of agriculture, and private labs display elemental P, K, Ca, Mg, and micronutrients in lb/ac (e.g., Virginia Tech), in parts per million (e.g., A&L Eastern Labs in Richmond, VA; 1 ppm = 2 lb/ac), or as an "index" value (e.g., North Carolina State Department of Agriculture.). Values are rated as:

VL (very low – critically deficient; NCDA index <10)
L (low – likely yield limiting; expect yield response to nutrient application; index 10-25)
M (medium – possible crop yield response to adding nutrient; index 26-50)
H (high – optimum, crop not likely to show response to added nutrient; index 51-100)
VH (very high – ample and possibly excessive; index >100)

Some labs (e.g. Virginia Tech) simply rate micronutrients as "sufficient" or "deficient."

Soil tests also shows soil pH, buffer index (pH measured in a buffer solution, used to determine lime rates), cation exchange capacity (CEC, the soil's ability to hold K, Ca, Mg, and other cation nutrients in plant available form, adsorbed to negatively charged clays and humus), and percentages of the CEC occupied by acidity (hydrogen + aluminum), Ca, Mg, and K.

Soil organic matter content (%OM) may be part of the standard test (A&L) or offered for an additional fee (VA Tech). NCDA measures "humic matter" (fulvic + humic acids), giving figures considerably lower than total OM.

Recommendations for lime, P and K applications are based on the soil test report and on research data on crop responses to nutrient applications on a wide variety of soils with different soil test values. At lower nutrient levels, more P and K are recommended than the crop is expected to remove in harvest, in order to ensure adequate crop response and restore soil levels. Recommended applications are closer to crop removal rate at high soil test nutrient levels. Liming rates are geared to adjusting soil pH to 6.5-7.0, based on pH and CEC, or on buffer pH.

NOTE: fertilizer recommendations are given in terms of phosphate or P_2O_5 (1 lb P_2O_5 = 0.44 lb elemental P) and K_2O (1 lb K_2O = 0.83 lb elemental K).

How to Use Standard Soil Tests in Organic Vegetable Production

Because research-based formulas do not exist for determining organic amendment rates based on soil test results, organic producers use the soil test somewhat differently from their conventional counterparts. An initial soil test can identify nutrient deficiencies and excesses, and pH imbalances that need to be addressed, and can help guide efforts to improve soil quality. For example suppose a farmer is bringing a new field into organic production, and the soil looks "farmed-out" with little organic matter and hardly any earthworms. The soil test might show an acid pH of 5.0 and low levels of P, K, Ca, and micronutrients. In this case, a generous application of composted poultry litter, followed by a heavy N-feeding cover crop like sorghum-sudangrass may be ideal. However, the test may reveal acid pH and *very high* P and K, because of a history of intensive use of conventional fertilizers. Legume cover crops, not poultry litter or other manures, are the best organic input for restoring this soil.

Organic farmers repeat soil tests every 2–5 years to monitor trends in nutrients, SOM, and pH. Soil samples should be collected at the same time of year, ideally at the same point in a crop rotation, and either consistently prior to, or consistently after tillage. Successive samples should be sent to the same lab to allow direct comparison. Repeat soil tests help the grower determine whether enough organic matter is being returned to the soil, whether more lime is needed, and whether P, K or other nutrient inputs need to be adjusted up or down to maintain optimal levels.

A note on liming: organic systems often require less lime, because good SOM and biological activity tend to buffer soil pH and widen crop pH tolerance ranges. In addition, many soils in the humid parts of the southern US should be limed only to about pH 6.0, to avoid lime-induced micronutrient deficiencies (Brady and Weil, 2008).

Ask the Crop: Foliar Nutrient Analysis

Organic farmers are well advised to conduct a *foliar nutrient analysis* on one or more major crops. This reveals what the crop actually "sees" in terms of nutrients, which may or may not match the soil test report. When crop deficiencies or imbalances are suspected, the farmer can take samples from an apparently healthy crop, and another that shows poor growth or deficiency symptoms (the same crop in two different fields, or different crops in the same or different fields), and compare results to identify limiting nutrients. A foliar nutrient analysis can also provide documentation to justify application of micronutrient amendments under the NOP.

On a deep, biologically active soil without hardpan, crops may show optimum levels of nutrients that test only "low" or "medium" in the soil, because roots can spread wide and deep, and soil organisms such as mycorrhizal fungi help plants access nutrients that are not detected in the soil lab. On the other hand, crops growing in a compacted, biologically-depleted soil may show deficiencies in nutrients that are "high" in the soil test, owing to restricted root growth or lack of beneficial organisms to help the crop take up nutrients

Direct field observations can also be revealing. For example, healthy, high-yielding peas, beans, or edamame in a field in which other crops do not thrive, and spring greens and brassicas do especially poorly, are a "smoking gun" for N deficiency, especially that caused by organic inputs with excessively high C:N ratios. A bad aphid problem in brassicas, plus lodging in a neighboring oat cover crop, may indicate too much N and insufficient K. If broccoli gives disappointing yields of poor quality heads and beet roots fail to grow to marketable size, while peas, onions, beans, sweet corn, and cucurbits are doing OK, check for a boron (B) deficiency.

USDA National Organic Program (NOP) Allowed Fertilizers and Amendments

Adjusting pH: Dolomitic or calcitic (high calcium) limestone to raise pH; elemental sulfur (S) to lower pH. (Hydrated lime, quicklime, and aluminum sulfate are prohibited under the NOP).

Nitrogen: Feather meal, blood meal, fish meal, and non-GMO seed meals are NOP allowed N fertilizers. Chilean sodium nitrate is allowed but restricted to 20% of a crop's N requirement. Legume cover crops can provide N much more inexpensively than purchased organic N fertilizers. (Urea, ammonium nitrate, potassium nitrate, and anhydrous ammonia are prohibited).

Phosphorus: Rock phosphate, calphos, colloidal phosphate, and bone meal are allowed P fertilizers. The first three are fairly insoluble, and only about 10% of the total is considered plant available. However, on a biologically active soil, most or all of the P becomes available over a 5-10 year period; thus, natural mineral phosphate fertilizers do not need to be applied every year. (Single and triple superphosphate, and ammonium phosphates are prohibited under the NOP.)

Potassium: Natural, mined potassium sulfate and sul-po-mag are allowed K fertilizers. Greensand (7%K) is sometimes used, but the K is mostly mineral-fixed and released very slowly at best; thus it is not economically effective as a K fertilizer. Grass hay mulches contain about 2% K on a dry weight basis, and a 4-inch mulch may deliver 200 lb K per acre or more. (Potassium chloride, also known as muriate of potash, is prohibited under the NOP.)

Boron: Borax, solubor, and the natural mineral sodium calcium borate are allowed under NOP when soil or foliar tests verify a need for B supplementation.

Calcium: lime (also raises pH); gypsum (does not raise pH).

Magnesium: dolomitic lime (raises pH), Epsom salts, sul-po-mag (these do not raise pH).

Sulfur: elemental sulfur (lowers pH), gypsum, potassium sulfate, sul-po-mag, Epsom salts (none of these significantly change pH).

Zinc, copper, manganese: sulfate salts and chelated forms of these micronutrients are allowed under NOP when justified by soil or foliar test results.

Some Examples from Actual Soil Tests

Following are some examples of soil test reports from Virginia Cooperative Extension, and possible recommendations for selected organic vegetable crops.

1. Field in Carroll Co., Virginia Crop to plant: cucumber

Nutrient	lb/ac	Rating	% of CEC	
P	39	H-		Soil pH: 6.0
K	213	H	4.3	Estimated CEC: 6.3
Mg	297	VH	19.4	
Ca	1446	H-	57.4	Micronutrients: all "sufficient"

Conventional recommendations: 870 lb/ac 10-10-10, delivering 87 lb each N, P_2O_5 and K_2O. 2,500 lb/ac agricultural limestone.

Suggested organic approach:

Lime may not be needed, especially if soil organic matter and biological activity are high. If lime is applied, calcitic or high calcium lime is preferred, as Mg is already quite high.

For a cucumber crop, recommendations include 100–125 N/ac, 50 lb phosphate (P_2O_5) for a "high" soil test P; and 100 lb potash (K_2O) for "high" soil test K (Peet, 1996).

If a rye + vetch cover crop containing 120 lb/ac total N is incorporated prior to planting, and compost with a N-P_2O_5-K_2O analysis of 1-1-1 is applied in crop rows at 2 tons/acre, the cover crop will make 60 lb N available to the vegetable, and the compost about 4-10 lb N (at 10-25% available), plus about 40 lb each phosphate and potash.

That leaves about 35 lb N, 10 lb P_2O_5 and 60 lb K_2O needed to meet recommendations. About 350 lb/ac fish meal (10-2-2) and 100 lb/ac potassium sulfate (0-0-51) will approximately provide these amounts.

NOTES:

a. Whereas a pH of 6.0 is sufficient for many vegetables, a few, including brassicas, beet, and asparagus, may prefer a somewhat higher pH. If these vegetables are next in the planned rotation, liming now will yield the desired pH increase by next season.

b. Applying Harmony (5-4-3) at 2,000 lb/ac, or increasing the compost application to 5 tons/ac would meet the N and K needs, but would apply considerably more P than will be needed by the crop, leading to a buildup of soil P. Whereas this is probably acceptable on this soil for a year or two, these practices may, over the long run, lead to a P excess in the soil.

c. The soil test did not include organic matter, and showed fairly low boron (B) at 0.3 ppm. A test by a different lab showed 3.6% organic matter with estimated nitrogen release (ENR) at 108 lb/ac, which suggests that the crop may derive sufficient N from soil organic matter, and the compost + cover crop are sufficient to replenish this organic N. The second test also confirmed low B; thus, 1 lb/ac elemental B would be recommended for brassica or beet family crops.

c. Because soil P and K tested in the "high" range, the current crop may show little yield response to additional nutrient; however, total P and K inputs should approximately replace the nutrients removed in harvest. A 10 ton per acre cucumber harvest would remove about 30 lb phosphate, and as much as 170 lb potash per acre.

2. Field in Carroll Co., Virginia, near sample 1, same farm, but different field history.
Crop to plant: potatoes

Nutrient	lb/ac	Rating	% of CEC	
P	821	VH		Soil pH: 7.2
K	447	VH	3.4	Estimated CEC: 16.8
Mg	522	VH	12.8	Micronutrients: all "sufficient"
Ca	5634	VH	83.8	Zn unusually high

Conventional recommendations: 225 lb/ac ammonium nitrate (33-0-0), or 75 lb/ac N.

Suggested organic approach:

P is in extreme excess; this combined with high Zn and Ca suggests a history of heavy poultry litter applications. K is ample. A second soil test confirmed the P excess and showed ample organic matter (5.7%, with ENR of 143 lb/ac/year).

The challenge here is to maintain organic matter, soil life, and mineralizable N levels for crop production without adding any more P. This is accomplished by stopping all applications of manure, poultry litter, and fertilizers or compost based on these materials, and relying on high biomass grass + legume cover crops to maintain organic matter and N levels. Limit compost to 1 ton/ac/year of a low-P compost rich in biological activity, to maintain soil microbial diversity. Use a fish-seaweed based foliar fertilizer if crops seem to need a boost.

NOTES:

a. Most vegetables should be able to obtain plenty of nutrients from this soil from organic matter breakdown by the soil life, without the need for organic fertilizer supplements. The extremely high P level may inhibit the activity of mycorrhizae, which could adversely affect some crops during drought, or leave crops more vulnerable to soilborne disease organisms. Crop harvests will gradually draw down P levels over time, especially heavy P feeders like potato.

b. Because potato actually prefers moderately acid soils (pH 5.5-6.0), the farmer may consider swapping the potato and cucumber crops with field 1 above, and postponing lime application in field 1 until after potato harvest.

3. Field in Giles County, VA Crop to plant: snap bean

Nutrient	lb/ac	Rating	% of CEC	
P	4	L		Soil pH: 5.3
K	329	VH	6.9	Estimated CEC: 6.2
Mg	134	M+	9.0	
Ca	1076	M	43.7	B low, other micronutrients suffic.

Conventional recommendations: lime 2.25 tons/ac; nutrients not shown

Suggested organic approach: Lime to achieve a soil pH of 6.0-6.5. Start with 1.5 ton/ac of Dolomitic Lime to provide both Mg and Ca, as Mg is quite low relative to K. Higher rates could tie up micronutrients or hinder release of P from rock phosphate (recommended below). If practical, start the crop rotation with acid-tolerant cover crops (buckwheat, oat, rye, vetch), or vegetables (potato, tomato, sweet potato), as the lime will take effect gradually over a two-year period. Retest soil at the end of that period; if pH remains below 6.0, apply another ton/ac of lime (calcitic is OK for second application).

Provide P as a combination of readily available (manure or compost based) and slow-release (rock phosphate or colloidal phosphate) materials. Grow high biomass legume-grass cover crops to build OM and the organic N pool.

For snap bean, recommendations include 40-80 lb N (assumes this legume crop will fix some but not all of its N requirement); 80 lb/ac phosphate for low soil test P, and just 20 lb/ac potash for very high soil test K (Peet, 1996).

Assume that the soil is limed and rye + vetch is planted the previous fall, and the cover crop produces a moderate biomass and 80 lb N/ac (40 lb/a available N). Prior to planting beans, spread 1,000 lb/ac rock phosphate or colloidal phosphate, which will slow-release phosphate over a 5-10 year period, with about 30 lb/ac P_2O_5 available the first season. If a good compost with a 1-1-1 analysis is available, apply at 2.5 tons/ac banded in the crop row to provide another 50 lb P_2O_5. This will also provide perhaps 10 lb available N (+ 40 lb available N from the cover crop = 50 lb total, which is enough), and somewhat more K_2O (50 lb/ac) than needed. Other vegetable crops in the rotation may utilize the extra K.

If compost is not available, use 5-4-3 fertilizer at 1,200 lb/ac, or poultry litter (1 ton/ac – at least 120 days before harvest to meet NOP requirements), to provide plant-available phosphate.

NOTES:

a. If the desired crop is blueberry, no lime is needed, as the pH is ideal for this crop.

b. Snap bean probably does not need boron, and can be damaged by too much. Boron should be applied at 1 lb/ac elemental B before growing brassicas, beet family, and possibly tomato.

4. <u>Field in Craig Co., VA</u>, on a limestone formation. Crop to plant: sweet corn

Nutrient	lb/ac	Rating	% of CEC
P	68	H	
K	400	VH	6.4
Mg	184	H	9.5
Ca	2589	VH	81.1

Soil pH: 6.5
Estimated CEC: 8.0

Micronutrients: all "sufficient"

<u>Conventional recommendations:</u> 870 lb/ac 10-10-10, delivering 87 lb each N, P_2O_5 and K_2O. No lime needed.

<u>Organic Nutrient Management</u>: K is ample, and high relative to Mg, so K inputs should be kept low to promote good nutrient balance.

Sweet corn requires about 150 lb N/ac, 80 lb P_2O_5 for high soil P, and 40 lb/ac K_2O for very high soil K (Peet, 1996). If the corn is preceded by a high biomass winter cover crop (legume + winter cereal grain) containing about 150 lb/ac N (of which 75 lb is available to the corn crop), an application of 1500 lb/ac Harmony 5-4-3 would provide another 75 lb N, 60 lb phosphate and 45 lb potash. Because the current soil P levels are not yield limiting, and the sweet corn harvest is not likely to remove more than 60 lb P_2O_5, this application may be sufficient. However, if an on-farm or local source of aged manure or manure compost is available that can provide N, P and K in approximately the right proportions, it may be more economical than the purchased fertilizer. Because its edible portion is tightly covered by husk, the interval between manure application and harvest under NOP rules is 90 days for corn.

References and Resources on Soil and Nutrient Management for Organic Systems

NOTE: much of the above discussion is based on the information provided by the following publications.

A&L Laboratories. Undated. *A&L Soil and Plant Analysis Agronomy Handbook.* 132 pp. Contact A&L Eastern Laboratories, Inc, Richmond, VA; 1-804-743-9401.

Brady, Nyle C., and Ray R. Weil. 2008. *The Nature and Properties of Soils, 14th ed*. Pearson Education, Inc., Upper Saddle River, NJ. 965 pp.

This soil science classic covers everything from soil taxonomy and mineralogy to nutrient cycles and nutrient management. The 14th edition, revised and updated primarily by co-author Ray Weil, fully incorporates recent research findings about the vital roles of soil life and soil organic matter in nutrient cycles and crop nutrition. This is a superb reference volume for anyone who seeks to develop science-based, site-specific recommendations for organic growers based on soil test reports and direct field observations.

Drinkwater, Laurie. 2003. *Nutrient Management in Organic Grain and Vegetable Systems*. Research report to Organic Farming Research Foundation. 17 pp.

Drinkwater documents N and P balance on organic vegetable and grain farms in New York, and presents a nutrient budgeting tool for balancing inputs and exports while maintaining high yields.
http://ofrf.org/funded/summaries/drinkwater-03s1-nutrient%20budgets.pdf

eXtension, the Extension Service Website, Organic Resource Area. 2009. Managing soils in organic production, including: nutrient cycling, nutrient and organic matter management, soil life and soil food web, nematodes, mycorrhizae, effects of tillage, and best tillage management. Listing of 18 articles and 7 video clips at: *http://www.extension.org/article/18602*.

Gugino, B.K., O.J. Idowu, R.R. Schindelbeck, H.M. van Es, D.W. Wolfe, B.N. Moebium, J.E. Thies and G.S. Abawi. 2007. *Cornell Soil Health Assessment Training Manual*, edition 1.2.2. Practical field and lab techniques for soil health assessment. Cornell University, Geneva, NY. 52 pp. Order at *https://www.nysaes.cornell.edu/store/catalog/*, or download at *http://soilhealth.cals.cornell.edu*.

Liebhardt, B. 2001. *Get the facts straight: organic agriculture yields are good.* Organic Farming Research Foundation Information Bulletin 10: 1, 4-5. *www.ofrf.org.*

Magdoff, Fred, and Harold van Es. 2009. *Building Soils for Better Crops, 3rd Edition*. Sustainable Agriculture Network (national outreach arm of SARE). Handbook Series Book 10, 294 pp. *www.sare.org*.

This volume covers all key aspects of ecological soil management: organic matter, soil life, soil conservation, crop rotation and cover crops, nutrient dynamics, and soil tests and recommendations, with specific examples. The new edition is beautifully illustrated with photos and diagrams, and includes several farmer stories. The authors take a "conservative" approach to fertilizer inputs to reduce input costs and protect environmental resources while sustaining good yields.

Peet, Mary. 1996. *Sustainable Practices for Vegetable Production in the South*. Focus Publishing, R. Pullins Company, Newberry, MA. 174 pp.

Includes nutrient recommendations based on soil test values for 12 major vegetable crops.

Seaman, Abby. 2009. *2009 Production Guide for Organic Cucumber and Butternut Squash for Processing.* Cornell University Cooperative Extension and New York State Department of Agriculture and Markets. 47 pp.

This publication includes a thorough discussion of nutrient management (pp 8-12), including step by step calculation of N, P_2O_5 and K_2O needs based on soil test results and credits from cover crop, manure and other organic inputs. This and three other guides by the same author on organic carrot, snap bean and pea are available at *http://nysipm.cornell.edu/organic_guide/.*

USDA Natural Resources Conservation Service. 1999. *Soil Biology Primer.* 50 pp.

Beautifully color-illustrated description of the web of life in soils under different vegetation types and management regimes, the role of the soil food web in soil health, and six major groups of soil organisms: bacteria, fungi, protozoa, nematodes, micro-arthropods, and earthworms.

Wander, Michelle. 2009. *Soil Fertility in Organic Systems: Much More than Plant Nutrition. http://www.extension.org/article/18636*;

Wander, Michelle. 2009. *Nutrient Budget Basics for Organic Systems. http://www.extension.org/article/18794*.

NOTE: phosphate recommendations in the Peet and Seaman references generally exceed amounts actually removed in harvest, and could eventually lead to a buildup of P surpluses in some soils.