Trent Gardens Soil Fertility Evaluation

Includes:
Final Report

By: Kirsten Thomson

Completed for: Trent (Vegetable) Gardens
Supervising Professor: Tom Hutchinson, Trent University
Trent-Centre for Community-Based Education

Department: Environmental Resource Studies/Science
Course Code: ERST 4830
Course Name: Community-Based Research Project
Completion Date: April 2010

Project ID: *961*

Introduction:

This report is the second of two done as a part of a project through the Trent Centre for Community-Based Education and the Trent Gardens. The first section of this project outlined basic principles of soil fertility management and went over general methods of understanding and interpreting soil fertility testing. This second report gives a more specific look at the results of the soil fertility testing conducted this year at Trent. The main results of the fertility test are set out, and suggestions and recommendations are provided.

Overview:

The most obvious feature of both roof and field gardens are the high-pH and predominance of calcium. This does not make Trent's soils particularly unusual. Calcareous soils are common throughout the County of Peterborough and high calcium results in a high pH. However, there are particular fertility issues to be aware of given these characteristics, particularly issues with phosphorus, potassium, and micronutrient uptake. Additionally, both gardens had generally low potassium and the field had low phosphorus. Both fields had good amounts of organic matter, which is a key measure of overall fertility.

pH and the Gardens: Soil Acidification?

Given the high pH of both soils and the common practice of adjusting pH in agricultural soils, the first research are investigated in this report was soil acidification. However, it turns out that acidifying a soil is much more difficult than is raising its pH, especially in the type of soil found at Trent.

Usually, acidification is done with elemental sulphur. However, given the heavier texture and high calcium, large quantities of elemental sulphur would be needed to change the pH of Trent's soils. A very general estimate for quantities of sulphur needed to drop the pH of the field by one unit would be between 3/4 and 1 tonne per acre. For the rooftop, 400-600 pounds per acre would be more reasonable (Magdoff, 2000). Alum (aluminum sulphate) is also used, but is six times less potent and would thus require even more.

Elemental sulphur is also expensive ($1000/tonne) and the quantity needed to change pH causes drastic changes in the soil chemistry which will have adverse effects on the soil micro-organisms and possibly the plants themselves. If soil acidification using elemental sulphur is pursued at any point, it would make sense to try it first on the rooftop before attempting it in the field. Elemental sulphur is usually less effective in calcareous soils, which could mean that multiple applications will be necessary. In general, soil acidification of high pH soils is not practiced within Ontario. OMAFRA soil fertility specialist Keith Reid suggested in agricultural magazine Better Farming that "it is not practical or economical" to acidify most Ontario alkaline soils (Reid, 2002).

Colloquial accounts of acidifying soil with pine needles, coffee grounds and cocoa shells abound. At the time of writing, I was unable to find any verifiable account of any of these being used on a larger scale to decrease pH. Peat does work, but is only practical on small scales. An investigation or experiment into the feasibility of using alternative substances to decrease pH might make an interesting student research project in future years.

I also asked OMAFRA soil specialist Keith Reid about the interactions between alkaline soils and calcareous well water, to determine whether or not irrigating the garden with groundwater from a well would further raise the pH. He suggested that the impact of the hard well water on ground pH would likely be minimal and not a serious concern.

Nitrogen:

A nitrate-nitrogen test was not done as a part of this year's soil testing. Nitrogen is very difficult to reliably test for, and nitrogen levels fluctuate so much throughout a season that a measurement of how much nitrate is plant-available at any one time is not particularly useful. Additionally, the test will not account for nitrogen added when green manures are ploughed into the soil in springtime (Gershuny and Smilie, 1999). The nitrate-nitrogen test is used mainly by conventional farmers who want to determine the appropriate amounts of fertilizers to use a side-dressing for crops. Because of this, OMAFRA recommends that growers intending to use a nitrogen test to determine fertilizers rates take their soil sample within 5 days of planting (Reid, 2007). If nitrogen levels are desired with any accuracy, a plant tissue test would be a better option.

A & L laboratories did provide Trent with a measure of estimated nitrogen release, based on the amount of OM in the soils. The ENR is based on average conditions, so it can actually understate the nitrogen (sometimes by as much as ½) released in soils which are very biologically active (Laing, 2006). The ENR at Trent was 60 lbs/acre in the field and

44 lbs/acre on the rooftop. Vegetable crops require variable amounts of nitrogen each year. Field beans usually require 50 lbs/acre, because they fix part of their own nitrogen supply. Lettuce, Jerusalem artichokes, and potatoes are around 75-120 lbs/acre, while brassicas and tomatoes can be up to 160 lbs/acre. These estimates come from the New England Vegetable Management Guide (www.nevegetable.org) and are based on commercial scale production, so may be generally higher than what is found at Trent. Nonetheless, they give a general estimate of how much nitrogen needs to be supplied into the soil.

The main methods of supplying nitrogen without resorting to chemical fertilizers are manure/compost and green manures or cover crops. Legumes usually supply between 80 and 150 lbs per acre of nitrogen, although this depends greatly on the particular legume and the length of time the it spends in the soil before being incorporated (Sarrantonio, 1994).

Manure or compost is another option for adding nitrogen. Composted manure is preferred to raw manure because it results in the addition of more humus, decreases possibilities of any kind of bacteria or infection, and releases nitrogen and other nutrients into the soil in a slower way that discourages leaching (COG, 1992). The nitrogen content of compost varies greatly, but a rough estimate is between 15-30 lbs N/tonne (COG, 1992).

These numbers suggest that the nitrogen needs of the field and rooftop are quite likely met through current practices, which involve the addition of some manure as well as a regular legume rotation and rotation of heavy and non-heavy feeding vegetable crops.

In order to get a more exact idea of the nitrogen balance of the soil, a test of the manure/compost sources used in the garden would be necessary. Theoretically, if the field mineralizes 60 lbs/acre nitrogen annually, and another 15-30 lbs N is applied in one tonne of manure/compost, the remaining N could be supplied by growing legumes as cover crops. 70-90 lbs/acre could supplied by sweetclover, which is currently included in the rotation.

A very rough nitrogen budget based on these estimate values and example three-year rotation of sweetclover, mixed vegetables, and beans/potatoes, might look something like this:

Year One: Manure added at 1 tonne/acre (+25 lbs/acre), mineralization occurs (+60 lbs/acre), annual sweetclover planted and fixes N (+80 lbs/acre) = 165 lbs N/acre left at the end of the season

Year Two: Sweetclover residue (winterkilled) incorporated in spring, manure+mineralization (+85 lbs N/acre), planted to vegetables which are harvested in the fall(-120 lbs N/acre). = 130 lbs N/acre left at the end of the season

Year Three: Potatoes/beans are planted in the spring and harvested in the fall (-100 lbs/acre), manure + mineralization (+85 lbs N/acre) = 115 lbs/acre N left at the end of the growing season.

This rough estimate demonstrates how the N needs of the garden could theoretically be met through small manure additions and cover cropping alone. However, in reality, not all the N contained in a green manure will be made available to the crops following it, and N will inevitably be lost due to leaching and runoff. Additionally, the rotation used in the garden is more complicated than a simple three-year, three-crop model. Finally, the numerical estimates used are generalizations, and may be quite different from those of Trent's compost, N production, and crop needs. For that reason, the amount of compost required might be closer to 2-3 tonnes/acre.

Nitrogen management recommendations for the garden would be to get manure and compost sources lab tested for N-P-K, so that rates of application can be determined more precisely. It may also useful to get a better idea of the N contributed by any green manure used. This can be done using a quadrat cut, which involves clipping the foliage from a small section, weighing it to calculate the dry matter per acre, and using this to estimate the nitrogen content. One method for doing this is described by Marianne Sarrantonio in her book "The Northeast Cover Crop Handbook", available from Rodale. Another general management recommendation would be to minimize the amount of time between green manures being incorporated and new crops being planted. Nitrogen contained in the green manure is very vulnerable to leaching once it has been incorporated into the soil and the process of mineralization begins. Depending on the weather conditions and state of the green manure, most of the nitrogen can be mineralized by soil bacteria after only a few weeks (Sarrantonio, 1994). Getting the next crop established as soon as possible after the green manure is done will help to stop this nitrogen from leaching away. This can mean planting a "catch" crop after plowing in legumes in the summer or following the vegetable crop. Brassicas like white mustard and oilradish are particularly good at this (Wallace and Scott, 2008), as are fall grains like rye. The more established they get before winterkilling, the better they are at taking up excess nitrogen.

Other nitrogen management options include underseeding the vegetable crops themselves with green manures. One method of doing this is described in Eliot Coleman's book "The New Organic Grower". In his mixed vegetable garden, Coleman underseeds most of his crops with leguminous green manures, often sweet clover or dwarf white clover (Coleman, 1995). Similar techniques have been found to work elsewhere. A study by the Nova Scotia Organic Growers Association was done on underseeding clover in brassicas (cabbage and broccoli) in the Maritimes, and most growers found the living mulch to be helpful. It reduced weeds, pest pressure, and sometimes even improved yields. But some farms also found that the mulch overtook the crop, causing reduced yield, or that it attracted new and different pests like slugs (Wallace and Scott, 2008). In any case, underseeding might be a useful and interesting technique to use at Trent, and could have the advantage of reducing time spent handweeding.

Phosphorus

The rooftop and the field had greatly different phosphorus levels. According to the bicarbonate test, generally the most accurate on alkaline soils, the field garden had 15 ppm or "low" phosphorus, while the rooftop had 32 ppm or "high" phosphorus.

High phosphorus often occurs as a result of applying only manure/compost to meet nitrogen needs, especially if the manure has been composted. The reason for this is that manure already contains quite a bit of phosphorus and, unlike nitrogen, phosphorus is not volatilized and lost in the composting process. So if manure is applied as the main way of meeting N needs, a slow buildup of phosphorus in the soil is quite common. (Magdoff, 2000) Some soils are also simply naturally high in phosphorus.

The main concern with high phosphorus is that is can end up in the surrounding surface waters and stimulate algae growth, leading to less dissolved oxygen in the ecosystem, hurting the ecosystem. (Busman et. al, 2002) High phosphorus can also interfere with the uptake of other cations (Wagner, 2006). The Ontario Environmental Farm Plan worksheets recommend trying to keep phospohrus levels around or below 30 ppm (OMAFRA, 2006). Because of this, it's probably a good idea to minimize phosphorus inputs to the rooftop in future years.

This doesn't mean that no phosphorous can be added. Because the rooftop has calcareous soils, some quantity of phosphorus added will be taken up by the calcium ions in the soil, forming compounds (calcium phosphate dihydrate, octocalcium phosphate, and hydroxyapatite) which are largely unavailable to plants and don't pose any threat. Phosphorus is also a key nutrient needed by plants, so available phosphorus will naturally decrease over time as long as the plants take up more than is added. At this point, a good goal would be to maintain phosphorus levels around 30 ppm (Laing, Ken, 2006), but to not let them climb much above that. Getting the manure and compost sources for the garden tested in a lab would be a first step towards determining their phosphorus content, and would help in determining whether the high rooftop phosphorus is a result of buildup from compost additions or whether it results simply from naturally high-phosphorus soils. In contrast, the field garden tested as having 15 ppm in the bicarbonate test, and 22 using the Bray II, and is rated as "low" or "medium" respectively. In general, it is a good idea to develop a plan for adding phospohorus if phosphorus levels are below 20 ppm (Laing, 2006), simply because most of the means through which phosphorus is added (rock phosphates) take a long time to become available.

However, given that composted manure is a major source of nitrogen in the field, sufficient phosphorus may already be added yearly, particularly if manure is being applied at the same rate it is on the rooftop. Given that the field hasn't been in cultivation for as many years, it is probably a good idea to wait a few years to see what effect the current rate of manure additions are having on phosphorus levels before considering further additions.

If phosphorus in the field is still low after a few years of manure additions, an easy way to add more phosphorus is by adding between 20-50 pounds of colloidal phosphate to every one tonne (around 2 cubic yards) of manure while it is composting. The composted manure will then contain more phosphorus, and the process of composting along with the manure helps to make it more available. Alternately, colloidal phosphate can also be spread directly on the field (Sullivan, 2001). However, the rate at which any kind of rock phosphate dissolved into phosphorus that the plant can use depends on the acidity of the soil. In calcareous, high pH soils, this process tends to happen much slower, which means that phosphate added directly to Trent's soils would become available very slowly and would become at least partially tied up by the large quantities of existing calcium (Mikkelsen, 2009).

Potassium

Both the field and the rooftop have relatively low available potassium (63 and 70 ppm). Potassium maintains processes like photosynthesis, movement of photosynthates throughout the plant, and regulation of water use (Thompson, 2006). Large amounts of potassium exist in the soil, however, only a tiny percentage of this total potassium is held in the soil solution and available to plants. High calcium (which Trent has) can interfere with potassium availability.

Potash, the source for potassium fertilizers, comes from deposits left in areas that used to be covered by oceans, or from existing salt marine deposits such as the Dead Sea or Great Salt Lake (Davies). Potassium is added to soils in several different compound forms. The most common one used in conventional agriculture is muriate of potash, or potassium chloride, but this isn't recommended in organic production because of concerns around chlorine accumulation and potential effects on soil micro-organisms. Under the current Canadian organic standards, muriate of potash is allowed but only if it does not cause a buildup of salts.

Other sources of potassium currently acceptable under organic standards include basalt, biotite, mica, feldspars, granite, greensand, and langbeinite (potassium sulphate magnesia). Wood ash, kelp meal, and manure are also good sources of K. All of these sources have advantages and disadvantages. Langbeinite is widely used but also contains magnesium and sulphur. Kelp meal contains relatively small amounts of potassium, and is often somewhat expensive. Greensand and other rock powders are usually low in plant-soluble K but are be good long-term sources. They are, however, often costly to transport and can be expensive to purchase. Wood ash has a variable potassium content and usually also contains phosphorus. It also raises the pH of the soil, which makes it an undesirable source of K for Trent's gardens (Mikkelsen, 2009).

A more detailed discussion of these amendments is found on the ATTRA website at: http://attra.ncat.org/attra-pub/altsoilamend.html#roc_min.

Manure also contains large amounts of K, and it is usually quite available to plants. Like phosphorus, K can accumulate in soils when manure is used as the main source of N. (Beegle, 2001) However, most of the K supplied by manure is in the urine, and major losses of potassium can occur due to leaching and runoff if manure is stored in the open. Because of this, if manure is to be used as a source of K it is important to use adequate bedding to soak up the liquid portion of the manure (Beegle, 2001). In general, sheep manure (currently used as a manure source in the garden) is high in potassium (COG) and if it is used to supply much of the nitrogen to the gardens, potassium needs should be met if leaching and runoff losses are not too high.

Magnesium:

Magnesium is a vital cation and an important nutrient taken up by plants. Many growers add magnesium as dolomitic limestone, however, this limes soil and would thus be a poor choice for Trent (Kinsey, 2006).

While the A & L rating for the quantity of magnesium present in the soils is “very low”, the actual quantity of magnesium may be entirely sufficient for most purposes.

OMAFRA does not currently suggest adding magnesium onto soils with a pH above 6 is necessary unless the soil tests at 20 ppm or below. The rooftop tested at 90 ppm and the field at 70 ppm, so magnesium may not actually be needed in significant quantities at this stage (OMAFRA, 2009). If magnesium is needed, OMAFRA recommends applying it at a rate of 27 lbs/acre of soluble magnesium (OMAFRA, 2009).

Soil magnesium deficiencies can actually be more of a problem for livestock producers, because animals pastured on magnesium-deficient soils can themselves become magnesium deficient. If livestock are ever a part of Trent's land, this may require more consideration.

Options for adding magnesium are magnesium sulfate (Epson salts) or langbeinite (potassium magnesium sulfate). Of the two, langbeinite contains less magnesium. Both of these are allowed under current organic standards to correct documented nutrient deficiencies.

Calcium:

Both gardens have ample calcium and adding more would be unproductive. Raising calcium levels should not be necessary in the foreseeable future.

Sulphur:

This year's soil tests did not test for sulphur, but it might be wise to include sulphur in future tests. It is responsible for the pungent taste of garlic and mustard crops, (buildingsoils),

Sulphur is vital to crop growth, and Ontario soils can be low in sulphur. Early farmers added sulphur in the form of gypsum (calcium sulfate) but in more recent years the need for sulphur is actually supplied by sulphur dioxide air pollution (http://www.plant.uoguelph.ca/performance_recommendations/ofcc/pub/sulfur.htm). Sulphur deficiencies have been found in some areas of Ontario, but mainly on sandier soils with low OM (OMAFRA, 2009). As sulphur dioxide pollution decreases, it may become necessary to add sulphur to the field.

Visual monitoring of micro and macronutrients:

Various other micronutrients are needed in small quantities by plants. The high pH of Trent's soils tends to makes several different nutrients less accessible (see diagram in the soil assessment report) and increases the potential for micronutrient deficiencies. Testing for micronutrients is usually done by plant tissue analysis, which is reliable but quite expensive.

Another option is simply to monitor plants for signs of nutrient deficiencies, both micro and macro. Most have visual signs, although they are not always easy to tell apart. One good source for getting an idea of how various micronutrient deficiencies is Thomas Wallace's "The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms". A copy is available in Trent's Bata library, but the book can also be found online at: http://www.hbci.com/~wenonah/min-def/index.html

Another good online source is found at: http://4e.plantphys.net/article.php?ch=3&id=289 This website is actually a portion of and supplemental materials for the textbook "Plant Physiology, Fourth Edition" and contains some very good pictures of the effects of major nutrient and micronutrient deficiencies.

Based on the pH of Trent's soils and the results of the soil tests conducted, deficiencies that might be expected in both the field and rooftop include magnesium, phosphorus, manganese, boron and zinc. Phosphorus deficiency could also be a problem in the field, although the soil test suggests that it should not be a concern on the roof. Most nutrient deficiencies cause some combination of chlorosis and necrosis. Chlorosis is caused by a lack of chlorophyll, and causes a yellow or pale colour in the leaf. Necrosis is the term to describe the actual death of cells, and usually appears as blackening. These symptoms are not necessarily a result of nutrient deficiency. Pest damage or heat/water stress can also cause chlorosis or necrosis. Additionally, different deficiencies can look very different on different plants. If patterns of necrosis or chlorosis are evident on a specific crop, it's probably a good idea to check out Wallace's book from the library or take pictures of the affected plants and compare them other photos online.

In general, the major nutrient deficiencies to be expected on Trent's alkaline soils cause the following effects:

Magnesium: chlorosis developing into necrosis in places. Dead "puckers" on leaf surface. Brassicas may develop orange, yellow, purple tints (Berry, 2004).

Manganese: light interveinal chlorosis (veins remain green, area in-between yellows). Begins with light chlorosis of young leaves. If the deficiency is more seveer, leaves become freckled and necrotic areas along veins develop (Berry, 2004).

Phosphorus: Stunted growth. Tomatoes, lettuce, corn, brassicas develop a purple tinge to stem and underside of leaves (Berry, 2004).

Zinc: Younger leaves yellow, pitting on mature leaves (Berry, 2004).

Boron: Light overall chlorosis. Boron deficiencies have major effects on fruit, and can result in pitted or soft-centered fruit, corky centers, rotting centers of root vegetables and damage to pith of cabbage stems (Wallace, 1943).

Iron: Begins as interveinal chlorosis, develops into overall chlorosis and loss of pigment until the leaf turns almost white (Berry, 2004). Affects younger leaves first.

Potassium: Marginal necrosis or "tip burn" giving leaves a scorched look. Veins generally stay green, but the interveinal areas might curl and crinkle, developing necrotic spots. Legumes and potatoes may show white speckling, freckling on leaves (Berry, 2004; Wallace, 1943).

Other measures of soil fertility and texture:

Other more subjective measures were used to evaluate Trent's field soils. A shake test of soil texture was conducted with one sample from the rooftop and five different samples from the field. Because the results of the shaker test turned out to be somewhat inconsistent and difficult to read, texture by feel was also conducted. The results from the were generally consistent with a clay loam (approximately 40% clay, 30% silt, 30% sand), but it is probably worth having a laboratory test the exact proportions in the future. The rooftop sample was a loamy sand (approximately 60% sand, 20% silt, 20% clay) according to both the shake test and the texture by feel approach.

Tests of the earthworm populations were also conducted using a mustard test. Three pitfall traps in 3 locations in the field, and three Berlese funnel traps were also built. All these evaluations followed the methodology listed in the online publication "The Willamette Valley Soil Quality Card Guide" in the chapter "Is the Soil Full of Living Organisms?". The evaluation the soil quality card systems uses for the Berlese funnel trap and the pitfall trap only evaluates the number of types of organisms present. Rather than identifying individual organisms, the Willamette Valley Soil Card System separates organisms into visually distinct categories in an attempt to evaluate soil ecosystem diversity. In both cases, the traps scored as 10 or "preferred". In the earthworm mustard test, the scale used by the Willamette soil card did not apply because the metal cylinder used (a 6.5 inch diameter tomato sauce can) was approximately half the area of the cylinder suggested by the Soil Quality Card Test. 6 earthworms appeared on the surface of the soil in 10 minutes, which is more than half of the number suggested as being "preferred" in the original test.

All three tests were conducted on October 17th, 2009. The temperature at the time was about 7 degrees Celcius and the skies were overcast. One heavy rain occurred before the pitfall traps were collected. The results of the Berlese funnel trap were looked at using a small 7x geographers hand lense.

The conclusion that can be drawn from this is that Trent's soils are quite biologically active. The surveying was done later in the year than optimal, when soils are usually less biologically active, but the results were still very good.

Recommendations:

Many of things which can be done to help the soil at the field and rooftop are already being practiced. General principles include:

1. Build humus:

More humus in the soil improves structure, holds moisture in the soil when it is needed, boosts the CEC, sequesters carbon, and increases the ability of the soil to mineralize nitrogen and make it available to plant roots. A rule of thumb is that, for every unit of pH above 4.5, there is 1 meq of CEC for every percent of organic matter. So building more organic matter in either field should greatly contribute to the CEC of the soil.

Adding compost is one way to add humus, as is cover cropping. When cover cropping to build humus, non-leguminous cover crops are important to include in the rotation because their greater amounts of harder-to-break-down carbon means they contribute more to the stable humus pool (Sarrantonio, 1994). For building organic matter, species that are recommended include sorghum-sudangrass, buckwheat, ryegrass (Sarrantonio, 1994), oats and fall rye (maritime cover)

This could be particularly important on the rooftop, which has a lower OM (to be expected, given its sandier texture). Sandy soils are easier to deplete of nutrients because of their CEC. Keeping the OM above 3% will help keep the CEC high and help retain moisture. One thing to consider is that most of the plants which contribute the fastest to humus pools are also more difficult to work into the soil, making them more difficult to work in on the rooftop.

2. Control erosion

Good soil is hard-earned, and erosion is the fastest way to get rid of it. While the Trent Garden is sheltered somewhat from the wind by trees, it is also quite sloped in places, which makes it more prone to wind and water erosion. Keeping ground covered or mulched as much as possible will help to make sure the precious organic matter and tiny clay particles are not blown or washed away.

3. Test compost for N-P-K.

The field is low in phosphorus, while the rooftop is high. Phosphorus levels change slowly (over a period of years) and before adding more phosphorus to the field it might be a good idea to determine how much is in the compost already being added. The field hasn't been in cultivation for very many years, so it is possible that phosphorus additions from previous years are still coming into effect. Testing the compost for phosphorus levels will help to determine if the field needs more phosphorus than is being supplied by the compost, or if the compost alone is sufficient to meet plant needs. Testing compost will also help develop a better idea of how much nitrogen is being added with compost additions, which would be useful for developing long-term green manure and cover cropping plans.

4. Amend soils

Amend soils with some supplemental magnesium and potassium to balance cations. Langbenite, a mined rock sold under the brand names K-Mag or Sul-Po-Mag, contains potassium and magnesium as well as sulphur. The field and the rooftop are low on both potassium and magenesium, and the added sulphur will not hurt the soil. Unfortunately, the marketer for K-Mag in Canda is Mosaic, who are owned by Canadian multinational Cargill. I was unable to find any other marketer of langbeinitite. Additionally, they recently stopped selling their "Natural" product, which was the one acceptable under organic certification standards. The regular line of K-Mag is the same product, but an oil is used to coat particles and keep dust down.

If K-Mag is used, usual application rates are 200-300 lbs per acre (Mosaic representative Randy Groff, personal communication; Laing, Ken, 2006). 200-300 lbs/acre K-mag will supply 36-54 lbs/acre Mg (Laing, Ken, 2006). Some sources recommend adding as much as 800 lbs per acre on heavier soils with nutrient levels similar to Trent's (Peaceful Valley Farm Supply, 2004), but it is probably prudent to stay within the 200-300 range, monitor effects, and repeat applications if needed. K-Mag is usually broadcast, which could easily be done by hand over the small area of the field garden. As of April 2010, K-Mag is available in Peterborough at Boyles Ernest and Sons Farm Supply at 2021 Bensfort Road. While they sell it ($18.50/25 kg) they do not always have it in stock, so it will likely need to be ordered in advance of when it is needed. Rural Routes on Lansdowne sells smaller bags aimed at home gardeners, though they said they could probably order in larger bags if needed.

Another option would be to add Epson salts, which add magnesium and sulphur without adding K. Epson salts (Given that both fields are currently also low in potassium, K-Mag might be a better choice. However, if potassium levels increase in the future, Epson salts could be a good way to slowly add magnesium. Epson salts contain about 30 lbs/acre Mg for every 300 lbs/acre applied.

5. Test soils regularly

Test soils regularly (once every two years) in order to monitor the effects of current practices.

Works Cited

Bates, T.E and Sheard, R.W (1988). "Sulphur and Sulphate Fertilizers –Do We Need Them?" Accessed online April 2010 from: xhttp://www.plant.uoguelph.ca/performance_recommendations/ofcc/pub/sulfur.htm.

Beegle, D., and Durst, T, (2001). "Managing Potassium for Crop Production". Penn State Agronomy Facts Handout Thirteen. Accessed April 2010 from: www.cas.psu.edu

Berry, Wade. "Symptoms of Deficiency in Essential Minerals". Topic 5.1 in "Companion to Plant Physiology, Fourth Edition." Accessed online April 2010 from http://4e.plantphys.net/article.php?ch=3&id=289

Busman, L., Lamb, J., Randall, G., Rehm, G., Schmitt, M., (2002). "The Nature of Phosphorus in Soils." University of Minnesota Extension Services. Accessed March 2010 from: http://www.extension.umn.edu/distribution/cropsystems/DC6795.html

Canadian Organic Growers, ed. Anne Macey. (1992) The Organic Field Crop Handbook. Ottawa: Canadian Organic Growers.

Canadian General Standards Board (2006). Organic Production Systems Permitted Substances List.

Gershuny, Grace and Smilie, Jow. The Soul of Soil: A Soil-Building Guide for Master Gardeners and Farmers, fourth edition (1999). White River Junction, Vermont: Chelsea Green Publishing Co.

Kinsey, Neal. Hands-on Agronomy. (2006). Austin, Texas: Acres USA.

Laing, Ken. Finding the Balance: Soil Testing and Amendments for Organic Farmers. (2006) Written pamphlet from the workshop run by Ken Laing and developed through the Ecological Farmers of Ontario and the Helen McCrea Peacock Foundation.

Magdoff, Fred. Building Soils for Better Crops (2000). Bulington, Vermont: University of Vermont.

Marr, Charles; Janke, Rhonda; Conway, Paul (1998). "Commercial Vegetable Production". Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Accessed online March 2010 from: www.ksre.ksu.edu/library/hort2/mf2343.pdf

Mikkelsen, Rob. "Managing P & K Fertility in Organic Systems". Presentation from the 2009 UC Davis Organic Soil Fertility Management Symposium. Accessed online April 2010 from: http://vric.ucdavis.edu/events/osfm_symposium_2009/osfm_presentations.htm

New England Vegetable Management Guide (2009). Published by Extension Vegetable Programs of the Universities of Maine, New Hampshire, Vermont, Connecticut, Rhode Island, and Massachusetts. Accessed online April 2010 from http://www.nevegetable.org/

OMAFRA (2009). "Soil Fertility and Nutrient Use: Fertilizer Recommendations". Accessed April 2010 from: http://www.omafra.gov.on.ca/english/crops/pub811/9fertilizer.htm#magnesium

OMAFRA (2006). Infosheet #17: Manure Management. Environemental Farm Plan Information Series. Accessed March 2010 from www.omafra.gov.on.ca/english/environment/efp/**infosheet_17**.htm

Oregon State University. Willamette Valley Soil Quality Card (2009). Publication EM-8711-E. Available at: http://extension.oregonstate.edu/catalog/abstract.php?seriesno=EM+8711

Reid, Keith. Nitrate-Nitrogen Test and Spring Barley. (2007) OMAFRA publication available online from: http://www.omafra.gov.on.ca/english/crops/facts/fert-rec-tables-2.htm

Reid, Keith (2002). "How important is the pH of your soil?". Published in Better Farming magazine (AgMedia), December Issue. Accessed online April 2010 from: http://www.betterfarming.com/archive/sb-5.htm

Sarrantonio, Marianne (1994). Northeast Cover Crop Handbook. Emmaus, PA: Rodale Publishing.

Sullivan, Preston. Alternative Soil Amendments. (2001). ATTRA Publication #IP054, available for download at: http://attra.ncat.org/attra-pub/altsoilamend.html#roc_min

Wagner, Julia (2006). "Brief Overview of Similkameen Valley Soil Health Assessment". Organic Agriculture Centre of Canada. Acessed online April 2010 from: http://www.organicagcentre.ca/ResearchDatabase/res_bc_similkameen_soil.asp

Wallace, Janet and Scott, Jennifer (2008). "Under Cover: A Guide To Using Cover Crops in the Maritimes" 2nd edition. Nova Scotia Organic Growers Association and Atlantic Canada Organic Regional Network. Accessed online April 2010 from: www.acornorganic.org/pdf/UnderCover2008.pdf