2009 Elba Muck Soil Nutrient Survey Results Summary, Part III: Calcium, Magnesium and Micronutrients

Christy Hoepting, Cornell Cooperative Extension Vegetable Program

Introduction

This is the final part of a 3-part newsletter article that describes the general nutrient status of the Elba muck land, based on a survey conducted in spring of 2009. In response to a finding that the Elba muck land was a major source of pollution into its local water shed, the Oak Orchard, delivering excessive amounts of phosphorus and nitrogen, free soil nutrient tests were conducted for Elba muck growers in hopes that they would apply nutrients according to the needs of their soils. In total, soil samples were taken from 21 "fields" or "blocks" which were approximately 10, 25, 50 or 100 acres in size, and often consisted of several fields. Two to 20 sub-samples were taken per "field/block" for a total of 160 sub-samples. Samples were analyzed by the Cornell Nutrient Analysis Laboratory (CNAL).

All of these soil test results were summarized by Christy Hoepting, Onion Specialist, Cornell Cooperative Extension Vegetable Program (CCE-VP). In addition to calcium, magnesium and micronutrients, all information from the soil tests including organic matter, pH, phosphorous, nitrogen and potassium, were reviewed and opportunities for improved nutrient management for onion production suggested. It is hoped that this will mark the beginning of collaborative efforts among onion growers, CCE-VP, Soil and Water Conservation Districts and EPA to reduce nutrient loading into the Oak Orchard and other water sheds, but also to improve onion yield and profitability by optimizing nutrient management.

In Part I and II of this article, opportunities for improved soil management were identified:

1) 13% of the soil sub-samples had less than 20% OM with the lowest reading being 2.4%. As OM decreased, pH increased. Some of this ground is being used to grow onions and should be managed differently with respect to fertility and certain pesticide applications.
2) A shift towards higher pH has occurred in the Elba muck land: 65% of the fields/blocks had pH higher than the optimum. Above pH 5.8 to 6.0, manganese (Mn), zinc (Zn), boron (B) and phosphorus (P) are tied up and can become deficient.
3) It is not possible to reduce soil pH by applications of sulfur on the calcareous/marly muck soils of the Elba muck land. Instead, pH, Mn and P need to be managed by using acidifying fertilizers applied in a band and foliar sprays.
4) 25% of fields had excessive levels of phosphorous, growers could cut P fertilizer for 3 years!
5) Phosphorous can become deficient where soil pH is greater than 7.0, which needs to be remedied by banding an acidified fertilizer and using foliar sprays.
6) Soil levels of potassium were generally excessive with some fields not likely needing additional K inputs for several years.
7) There is much opportunity to improve the efficiency of N use in onion production by using PSNT tests, experimenting with using less N fertilizer in the spring and adding more if necessary according to a PSNT, experimenting with controlled release fertilizers and nitrogen inhibitors, and planting cover crops in the fall to capture N that is not used up by the onion

crop. Ultimately, growers can save money on N input costs while reducing environmental pollution.

Calcium and Magnesium are abundant, foliar applications of Ca are not necessary

Calcium (Ca) and magnesium (Mg) are secondary plant nutrients that are abundant in the Elba muck land. An early Cornell study conducted in the Elba muck land showed that a single 450 cwt per acre onion crop removed 60 and 5 lbs of Ca and Mg, respectively. According to the Cornell recommendations, Ca soil levels are considered low when there is less than 1000 lbs per acres, soil levels are medium when there are 1000 to 2000 lbs per acre, and are high when there is more than 2000 lbs per acre. According to the 2009 Elba muck soil survey, the majority (67%) of the fields/blocks had calcium levels between 20,001 and 30,000 lbs per acre; an additional 19% had levels higher than this with the highest recording of a sub-sample being 48,380 lbs Ca per acre (Figure 1). No fields/blocks had Ca levels less than 2000 lbs, although the lowest sub-sample was 1620 lbs per acre.

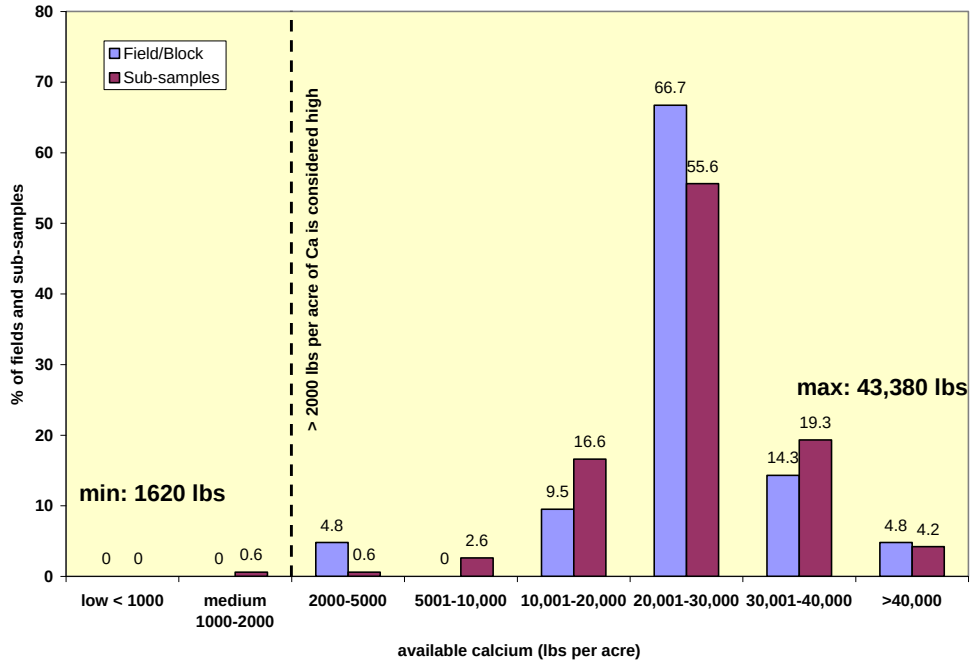

Figure 1. Soil survey, Elba muck, Spring 2009: Available calcium for 21 fields/blocks and 160 sub-samples.

According to the Cornell recommendations, Mg is considered high when it is between 200 and 500 lbs per acre. In the Elba muck soil survey, the lowest recording of Mg was 220 lbs per acre (Figure 2)! The majority (86%) of the fields/blocks had Mg levels between 1000 and 3000 lbs per acre with the highest recording of a sub-sample being 3700 lbs per acre!

As organic matter is decomposed, Ca and Mg are released and levels may nearly double over a 10 year period. With the Elba muck land having been farmed for almost 100 years, and the underlying material being marl, such high levels of Ca and Mg may actually not be as surprising as they first seem. In the Elba muck survey, there was a trend that as organic matter (OM) increased, Ca increased. The lowest Ca levels in the survey (< 5000 lbs per acre) occurred where the soil OM was less than 10%.

Calcium and Mg bind very strongly to the exchange sites on organic matter in muck soils, and compete with binding sites with K. In the 2009 Elba muck land survey, it did not appear that the high levels of Ca and Mg reduced the availability of K, due to the generally excessively high levels of K (see Part II). Instead, there was a slight trend that as Ca and Mg increased, K also increased. Where the soil level of K was low (<200 lbs per acre), the Ca levels ranged from 10,000 to 30,000 lbs per acre (data not shown). In the soil sample that had the highest level of K (6790 lbs per acre), the Ca was >35,000 lbs per acre.

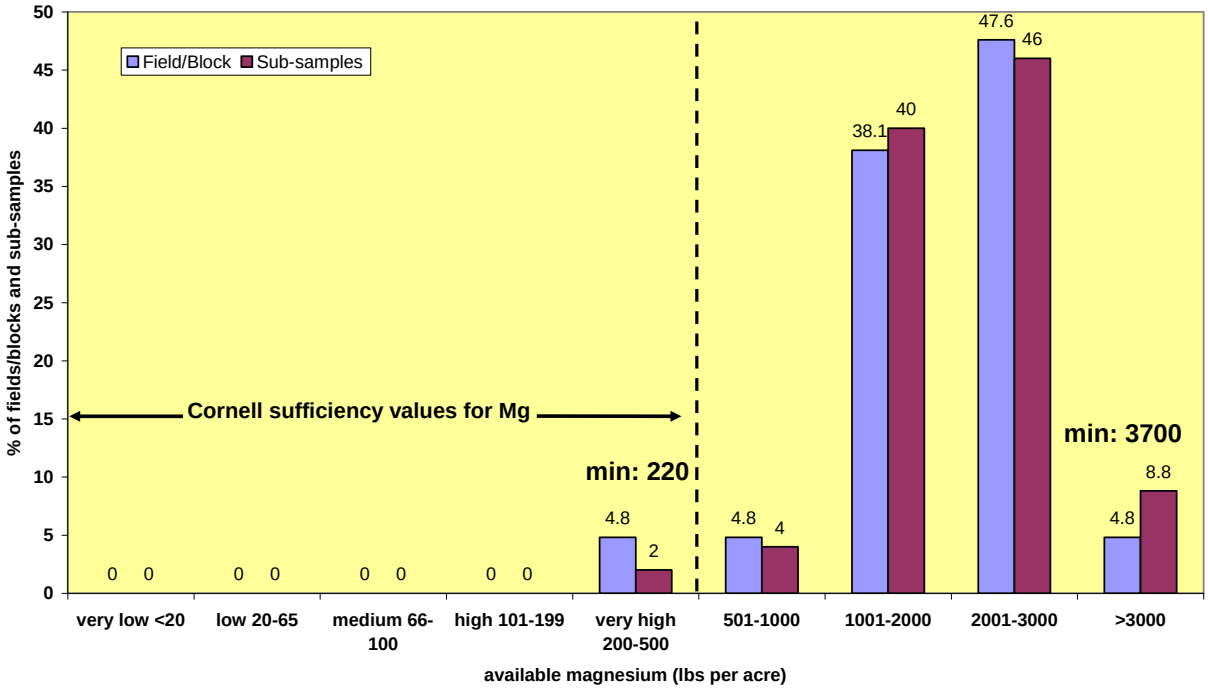

Figure 2. Soil survey, Elba muck, Spring 2009: Available magnesium for 21 fields/blocks and 160 sub-samples.

The availability of Ca and Mg can be reduced when pH falls below 5.0 or rises above 6.0. With the excessive soil levels in the Elba muck land, there was no relationship between pH and Ca and Mg. In the sub-sample where the pH was the lowest (4.6), Ca and Mg were 23,030 lbs and 1450 lbs per acre, respectively. Above pH 6.0, soil levels of Ca and Mg were evenly distributed from very high to extremely high. Calcium and Mg are moved to plant roots in water; if at all, a deficiency would more likely occur when soil conditions are very dry.

Although foliar application of Ca has proven beneficial in places where onions are grown on sandy loam soils, such as in Georgia, this was not the case in several studies conducted on muck soil in Michigan. Three foliar applications of 36% calcium chloride applied at 10, 20 and 30 gal per acre at the 4-5 leaf stage followed by 2 subsequent applications 2 weeks apart, did not improve onion yield or bulb size. In fact, any more than 2 applications of the 10 gal per acre rate reduced yield and the highest rates caused severe leaf injury. The recommended rate of 10 gal of 36% calcium chloride in 30 gal water supplies 15 and 27 lbs per acre of calcium and chloride, respectively, per application; the chlorine may be what is causing the injury. Given the very high soil levels of Ca in the Elba muck land, it is very unlikely that an onion crop would benefit from foliar applications of Ca, unless, perhaps soil conditions were extremely dry. Caution should be used when using calcium chloride as a source of Ca, because it can cause foliar injury.

Magnesium can become deficient if the ratio of Ca: Mg is greater than 10:1. In the Elba muck survey, 81% of the fields had a Ca: Mg ratio between 10 and 15, 10% had a ratio higher than 15, while only 6% had a ratio less than 10. Despite this disproportion between Ca and Mg, and the shift towards the muck having a pH above the optimal range, available Mg occurs at extremely high levels in the Elba muck, and a Mg deficiency would be very rare. In most situations, addition of calcium and magnesium is not necessary. When calcium or magnesium is in a fertilizer used primarily to supply another nutrient its effect would be non consequential.

Manganese is abundant in the Elba muck – are additions of Mn fertilizer really beneficial? Onions are sensitive to manganese (Mn). A Cornell study conducted in the Elba muck land showed that a single 450 cwt per acre onion crop removed 2.8 oz per acre of Mn; thus, it would take about 6 years to remove 1 lb. According to Cornell recommendations, the potential for plant toxicity from Mn is considered low, medium and high when soil concentrations are less than 10, 11 to 50 and 51 to 100 lbs per acre, respectively. In the 2009 Elba muck survey, 57% and 38% of the fields/blocks had a medium and high potential for toxicity, respectively (Figure 3). Sixteen percent of the sub-samples had soil levels of Mn greater than 100 lbs per acre with the highest recording being 725 lbs per acre! Despite such high levels, Mn toxicity generally only occurs when the soil pH is near or below 5.0. When the pH is above 6.0 it would be quite unusual for Mn to be toxic.

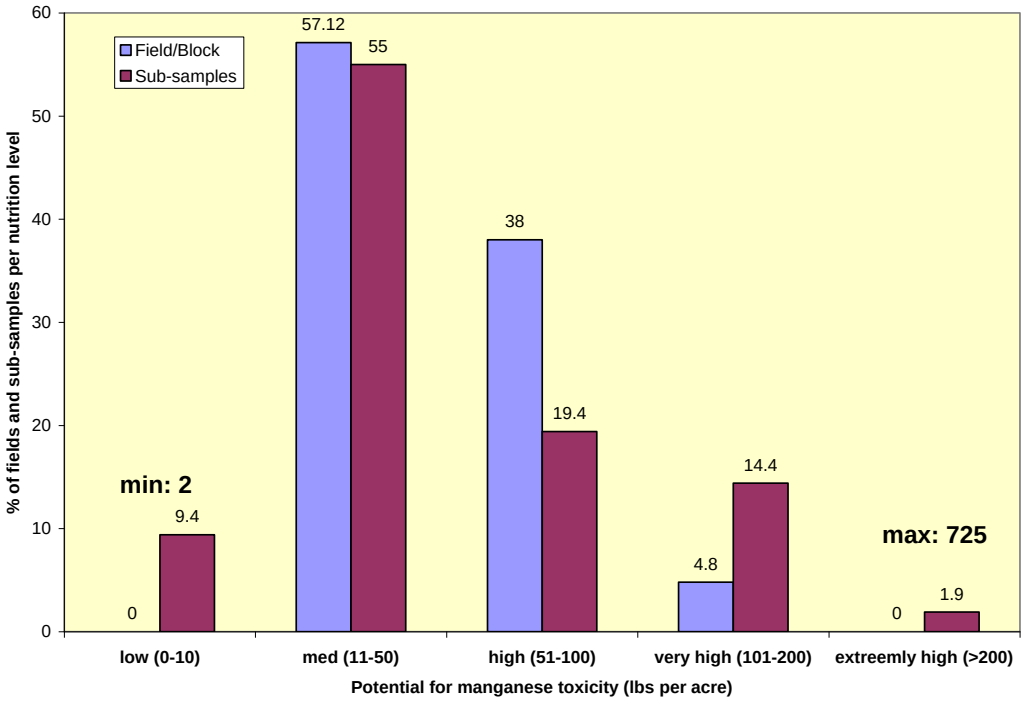

Figure 3. Soil survey, Elba muck, Spring 2009: Available manganese for 21 fields/blocks and 160 sub-samples.

Below pH 5.0, Mn availability is greatly increased and is taken up in toxic amounts. Symptoms of Mn toxicity are similar to Mn deficiency and include chlorosis, leaf die back and stunted roots. It can occur when soil levels are 70 to 100 lbs per acre, especially when Al and Fe are also high. In the 2009 Elba muck land survey, Mn availability was high (> 50 lbs per acre) in

all of the 6 sub-samples where the pH was 5.0 or less (Figure 4). However, where the highest recordings of Mn (> 250 lbs per acre) occurred, the pH was within the optimal range of 5.2 to 5.8. In fact, of the 80 sub-samples that had high potential for toxicity, 67 (83.7%) of them occurred within the optimum pH range for growing onions on muck. In general, levels of Mn have increased compared to a muck soil survey of all of New York State that was conducted in 1953 and 1954. In this survey, 44% of 585 samples had low levels of Mn (compare to 0% in Elba 2009), 33% were medium (compare to 57% in Elba in 2009), 16% were high (compare to 38% in Elba 2009) and 7% had more than 100 lbs per acre (compare to 5% in Elba 2009). The abundance and apparent increase in available Mn in the Elba muck, begs the question whether additions of Mn fertilizer are beneficial? Closer attention to high soil Mn levels and the potential of Mn toxicity to onions is warranted.

Manganese can be deficient when pH is above 6.5

Availability of Mn is reduced when pH is greater than 6.0 and is most likely to be deficient in muck soils when pH is above 6.5. Manganese deficiency symptoms in onion include slow growth, curling of leaves, light colored foliage, burning of leaf tips, delayed bulbing, and thick necks. In the 2009 Elba muck survey, there was a trend that availability of Mn decreased as pH increased (Figure 4). The lowest recorded available Mn (2 lbs per acre) occurred where the pH was 6.7 and 7.2. Out of the 10 sub-samples where Mn was low (<10 lbs per acre), 9 (90%) of them had a pH of 6.0 or greater. However, the available Mn in the sub-sample with the highest pH (7.6) was high (81 lbs per acre). In the Elba muck land, higher pHs tended to occur where OM was less than 20%, or in shallow muck areas. These are the areas where a Mn deficiency would most likely occur. It is important to not assume that there will be a Mn deficiency in shallow muck or where pH is high, because this was certainly not always the case, another reason to have soils tested regularly.

Onions are highly responsive to additions of Mn when soil tests are low. When pH is above 6.0, soil applied Mn is readily bounded into unavailable forms. Therefore, to remedy an Mn deficiency, Mn should be applied to soil only as a band in an acid forming fertilizer, such as manganese sulfate. When soil pH is high, using this technique will also increase the availability of phosphorus, boron and zinc. In addition to applying Mn to the soil in an acidic fertilizer band, foliar applications, may also be necessary. In a Michigan study of onions grown in muck soils, application of 2 lbs per acre of Mn as manganese sulfate at the 2-3 and 5 leaf stages, increased total yield by 10 to 80% and the percentage of bulbs > 2.5 inches by 10 to 90%. It is unknown how the soil levels of Mn in these studies compares to the Elba muck land, because each university uses different soil testing procedures. In 2010, we will send some soil samples to both laboratories to compare results.

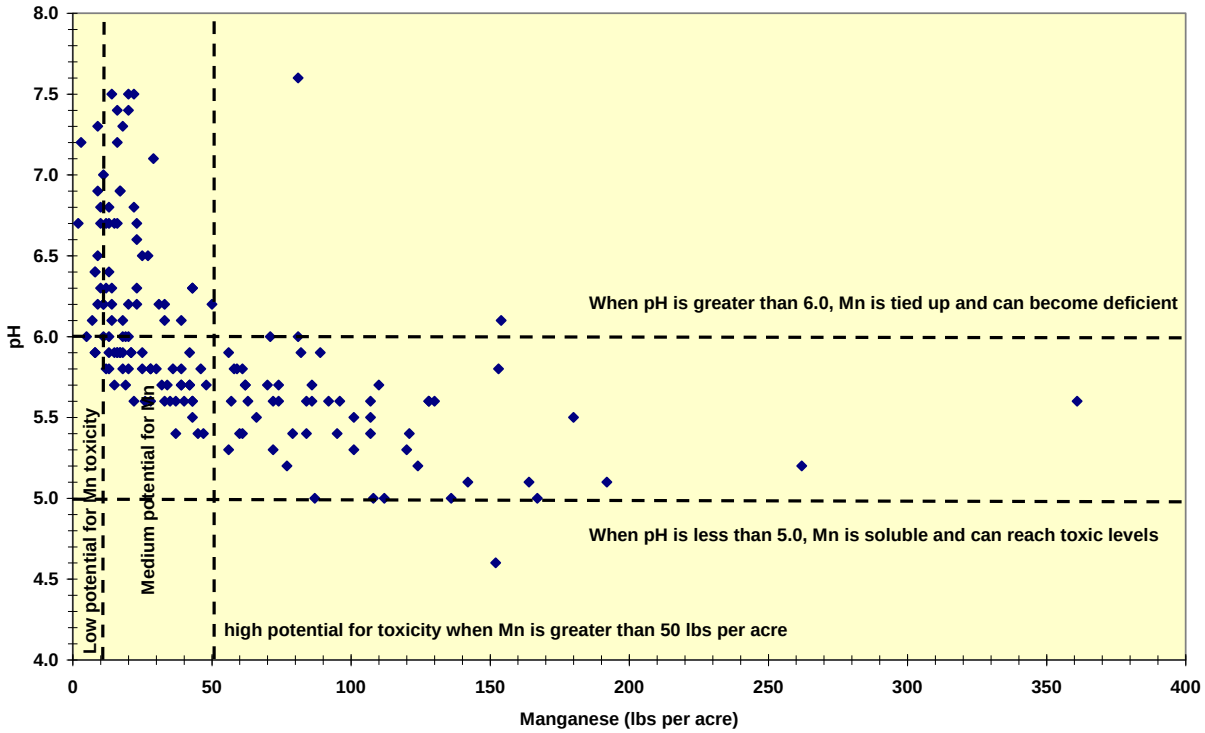

Figure 4. Soil survey, Elba muck, Spring 2009: relationship between pH and available manganese in 21 fields/blocks and 160 sub-samples.

High soil levels of nitrogen may also induce a Mn deficiency. This did not appear to be an issue in the Elba muck land. Out of 14 sub-samples where available nitrogen levels were very high (> 150 lbs per acre), in only one (14%) of them was the level of Mn low (< 10 lbs per acre) (data not shown).

Zinc also plentiful in the Elba muck land

Zinc is an important micronutrient to onions and when soil tests are low, onions are highly responsive to applications of Zn. A Cornell study conducted in the Elba muck showed that a single 450 cwt per acre onion crop removed 3.5 oz per acre of zinc (Zn); thus, it would take 4 years to remove 1 lb. The potential for zinc toxicity is low, medium and high when soil levels are <0.5, 0.5 to 1.0 and >1.0, respectively. Zinc can be easily built up and maintained in muck soils over time. In addition to fertilizer applications, Zn is added to muck soils via fungicide use, specifically EBDCs like mancozeb and maneb, which are applied directly to the soil as an in-furrow treatment for control of onion smut, and as a foliar application for control of leaf diseases, especially downy mildew. The 2009 Elba muck land soil survey showed that all of the 160 sub-samples had high levels of Zn with the majority (60%) being between 1.0 and 20 lbs per acre. An additional 29% of the sub-samples had 21 to 50 lbs per acre and the highest soil level of Zn recorded for a sub-sample was 1698 lbs per acre! At such high levels, it is expected that zinc would be toxic to onions.

Like Mn, the availability of Zn is reduced when the pH is greater than 6.0. In the Elba muck land soil survey, more than half of the fields/blocks and sub-samples had a pH greater than 6.0. Similarly, high soil levels of phosphorous (P), which occurred in 25% of the fields/blocks in

the Elba muck soil survey, can tie up Zn and induce a deficiency. However, the very high soil levels of Zn compensate for any reduction in availability that could be induced by high pH or P. In general, there should be no need to apply additional Zn to onions in Elba. It is not feasible to try to reduce soil levels of Zn.

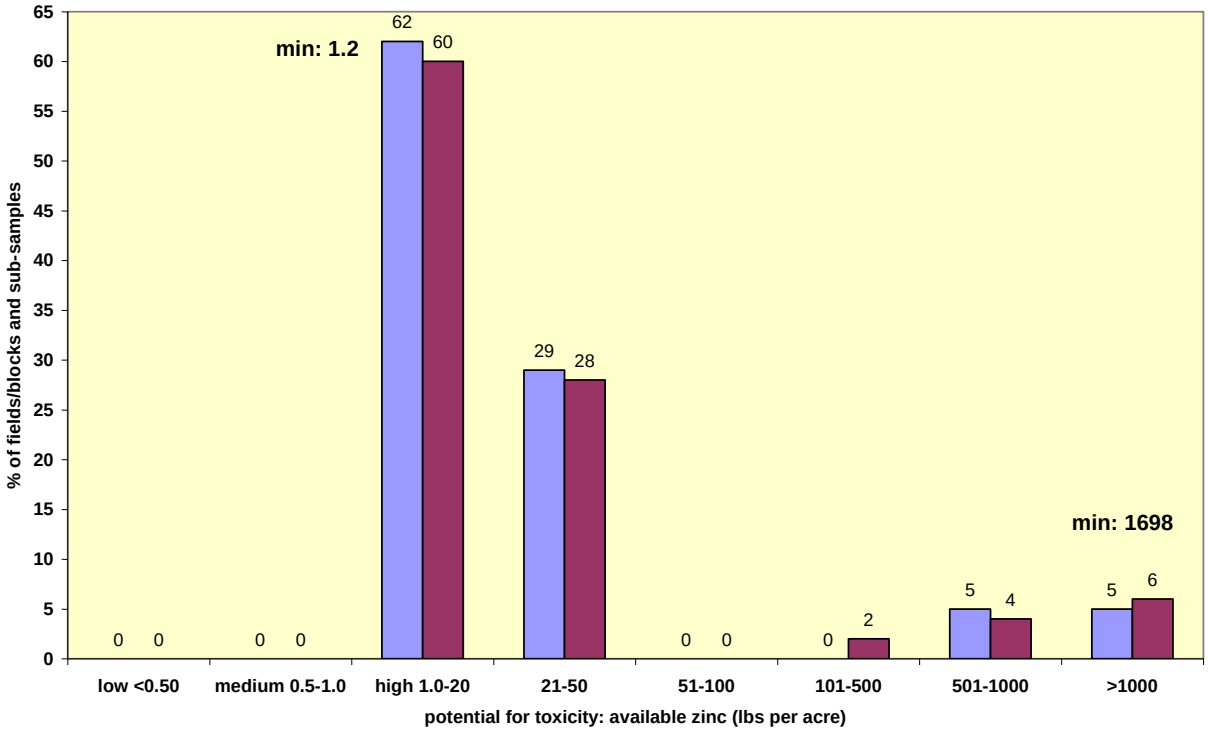

Figure 5. Soil survey, Elba muck, Spring 2009: available zinc in 21 fields/blocks and 160 sub-samples.

Iron and Aluminum

In a Cornell study conducted in the Elba muck, a single 450 cwt per acre onion crop removed 3 oz per acre of iron (Fe); thus, it would take about 9 years to remove 1 lb. In the 2009 Elba muck land soil survey, available Fe was less than 10 lbs per acre in 42% of the fields/blocks and between 10 and 50 lbs per acre in 42% of the fields/blocks (data not shown). Iron was greater than 50 lbs per acre in 16% of the fields with the highest recording in a single sub-sample being 447 lbs per acre! Even though these muck soils contain a lot of extractable iron, the iron is not readily taken up and is not very toxic even at high levels in plants.

The potential toxicity of aluminum (Al) is considered low, medium and high when soil levels are < 50, 50 to 100, and > 100 lbs per acre, respectively. In the 2009 Elba muck land survey, the potential toxicity from Al was low in 32% of the fields/blocks and medium in 58% of the blocks/fields (data not shown). Ten percent of the fields/blocks had a high potential for Al toxicity with the highest recording of a single sub-sample being 179 lbs per acre. Toxicity is a concern if Fe + Al is greater than 200 lbs per acre. In the Elba muck land survey, this occurred in only 15 out of the 160 sub-samples (9.3%) (data not shown).

When pH is below 5.0, Fe and Al become soluble in the soil and can be taken up in toxic amounts. In the Elba muck, pH occurred below 5.0 in only one sub-sample, and Fe was not especially high in this soil sample (data not shown). The highest levels of Fe (> 50 lbs per acre)

occurred where pH was between 5.0 and 6.5. The lowest levels of Fe (< 10 lbs per acre) occurred where pH was between 5.0 and 7.3. Similarly, the highest soil levels of Al (> 100 lbs per acre) occurred where pH was between 5.1 and 5.8 while the lowest (< 50 lbs per acre) occurred where pH was between 5.3 and 7.5.

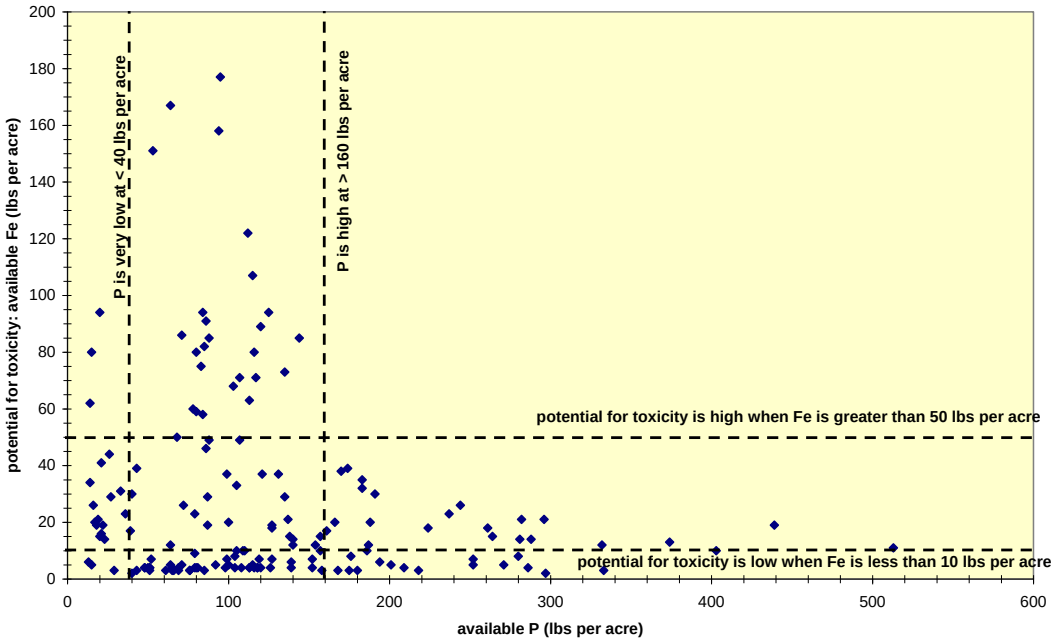

Figure 6. Soil survey, Elba muck, Spring 2009: relationship between available phosphorus and iron in 21 fields/blocks and 160 sub-samples.

When Fe comes into the soil solution, it will form iron phosphates and tie up P. Out of the 29 sub-samples in the Elba muck land survey where Fe was high (> 50 lbs per acre), P was deficient in only 3 (10%) of them (Figure 6). Alternatively, when P is excessive, it may cause a Fe deficiency. Out of the 39 sub-samples where P was high (> 160 lbs per acre), 15 (39%) of them had low (< 10 lbs per acre) levels of Fe.

Copper, Sulfur, Boron and Molybdenum

Copper (Cu), sulfur (S), boron (B) and molybdenum (Mb) are other micronutrients that the standard Cornell soil test does not analyze. The most important to onion production are copper and sulfur. A Cornell study conducted in the Elba muck showed that a single 450 cwt per acre onion crop removed 0.7 oz per acre of Cu; thus, it would take 23 years to remove one pound. Clearly, onions do not need a lot of Cu, but it is an important micronutrient and onions are highly responsive to additions of Cu when soil tests are low. In virgin muck, Cu is a limiting factor. Copper deficiency results in light colored scales and is most likely to occur in a hot dry season and on well drained muck. However, it is readily built up over time via fertilizer and copper bactericide applications, both of which can be used judiciously, especially during wet seasons. It would be very interesting to see how soil tests read for Cu, as I would expect them to also be quite high.

Onions use and accumulate large amounts of S, as it plays an important role in flavor and pungency. Muck soils contain more than adequate amounts of S, which is mostly bound in the organic materials and just like N, it is released as microorganisms decompose the organic matter.

Onions grown on muck soil are of superior quality compared to onions grown on mineral soil, because the high S content of muck soils improves onion flavor, cooking quality and storability. It would be interesting to see what the soil levels of S are on muck soils with low organic matter (i.e. 20-30%). Ever wonder what the whitish salt-type looking stuff seen on the surface of drying mucks is? It is calcium sulfate, which is formed when S and Ca react with each other in muck soil.

Onions are not very responsive to B; they are generally tolerant to toxicities and deficiencies are seldom. The Cornell study conducted in the Elba muck showed that a single 450 cwt per acre onion crop removed 1.7 oz per acre of B; thus, it would take 9 years to remove 1 lb. Boron is subject to leaching loss with high rainfall. Deficiency may also occur under dry conditions, because like Ca and Mg, it is moved to the root zone in water. On a soil test, less than 0.5 lbs per acre is considered deficient, and greater than 0.75 lbs per acre is sufficient. Molybdenum deficiency is most likely to occur in very acid soils, pH below 5.2; liming usually solves this problem. If deficiencies occur, B, Cu and Mo may be applied as foliar sprays at rates of 0.1-0.3, 0.5-1 and 0.06-0.1 lbs per acre, respectively.

Summary:

- The Elba muck land has been identified as a major source of pollution into its local water shed, delivering excessive amounts of phosphorus and nitrogen.
- In response to these results, free soil nutrient tests were conducted for Elba muck growers in hopes that they would apply nutrients according to the needs of their soils. Together, the soil test results made an extensive database, the summary of which, is being presented in these three (Part I, II and III) newsletter articles.
- Calcium and magnesium consistently occurred at very high levels in the Elba muck land. Foliar applications of Ca are rarely necessary.
- Despite deficiencies of Mg and K that could be induced by high Ca, levels of these nutrients in the Elba muck land are high enough to compensate for any reductions caused by high Ca.
- Similarly, levels of Ca and Mg in the Elba muck land are too high to become deficient when pH falls below 5.0 or above 6.0.
- Generally, Mn occurs at very high levels in the Elba muck land; fertilizer applications are generally not necessary.
- Watch out for Mn deficiency where soil pH is greater than 7.0, which can only be remedied by an application in a band with an acidifying fertilizer such as manganese sulfate, plus foliar applications.
- Soil levels of zinc were consistently very high in the Elba muck land, a likely accumulation from inputs of fertilizer and Zn-containing fungicides, mancozeb and maneb. As is the case with Ca and Mg, levels of Zn are too high to become deficient when pH is below 5.0 or above 6.0. Zinc can be reduced from fertilizer applications without having any impact on yield. In some cases, zinc may even be toxic to the onions.
- Iron occurs at high levels in the Elba muck land. Concerns for toxicity occur when levels of Fe+Al are greater than 200 lbs per acre, which occurred in only 9.3% of the sub-samples.
- Copper is deficient in virgin muck, but accumulates easily with the judicious amount that is added over the years in fertilizer and copper bactericides. Sulfur, B and Mo are also generally not expected to be deficient in muck soils for onions.

Regular soil testing is a great way to efficiently manage the fertility needs of your onion crop, while increasing profitability and reducing pollution of the waterways!

2009 Elba muck land soil survey results available

If there are any growers who would like copies of their soil test results, maps and recommendations, or for information on the database, contact Christy Hoepting (585-721-6953; cah59@cornell.edu). Look for "Part I: Organic Matter and pH" and "Part II: Phosphorus, Potassium and Nitrogen" in previous issues of *Veg Edge*.