

## Chapter 3: Understanding Your Berry Soil Test Results – *Dr. Marvin Pritts, Cornell University*

### Let's review

The goal of soil testing is to estimate the plant-available nutrient levels in soil. Soil tests do not tell you how much of a particular nutrient is in soil, they estimate how much of a particular nutrient in soil is available to the plant. So the extractant mimics what a plant root might have available to it; they don't do this perfectly so a variety of

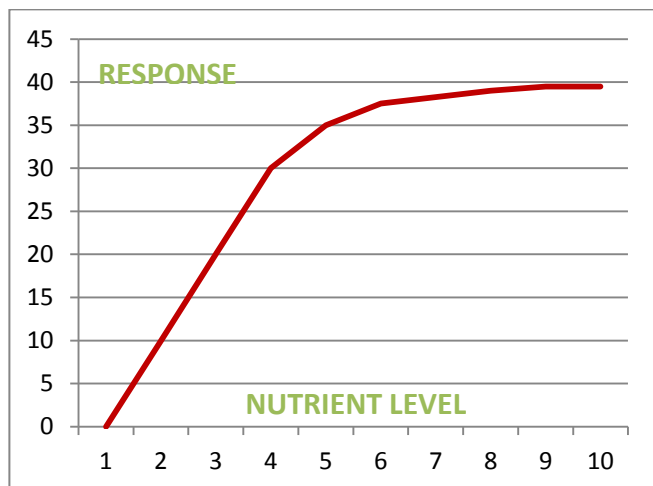
**Continued below**

extractants have been developed, each with their own unique advantages and disadvantages (i.e. *Bray, Olsen, Mehlich III, Morgan, Modified Morgan, Sodium bicarbonate*); no extractant is perfect.

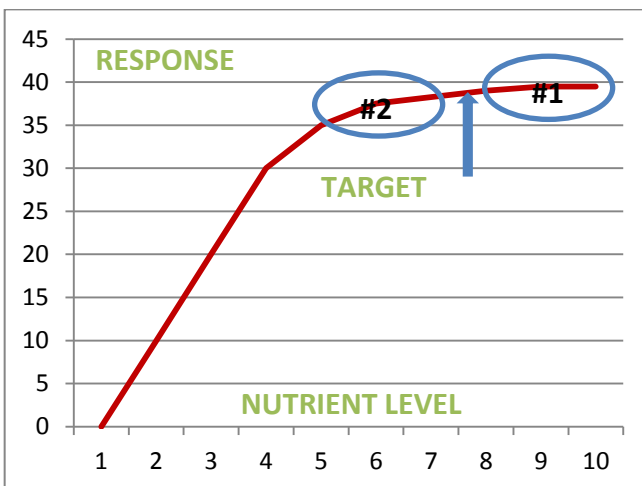
## Soil test recommendations

Ensuing test results are accompanied by recommended levels of amendments to bring up levels to some optimum (Figure 2a). Recommendations from different labs have different philosophies. Some want to build up the soil nutrient bank so there is never any risk of nutrient being limited (#1). Others want to apply just enough to where the economic gain from the additional amendment is equal to the cost of the added amendment (#2).

**Figure 2a.** Plant response curve



**Figure 2b.** Recommendation philosophies



For berries and other perennials crops the ideal is somewhere between #1 and #2 because of the difficulty of incorporating nutrients annually (Figure 2b). So it's best to add P, K, Ca, and Mg prior to planting as they need to be incorporated for best effect.

So, except for sandy soils, the eventual nutrient supply (soil repository plus fertilizer) should be mostly sufficient for the life expectancy of the planting- without annual supplementation (apart from nitrogen). Nitrogen is rapidly lost from soil through use by plants and microorganisms, and leaching; it moves easily into the rooting zone with annual applications. Conversely, it is difficult to move nutrients like phosphorous and potassium into the root zone when perennial plants are already established. That makes it important to build up a little bit of a bank for long lived crops like raspberries and particularly blueberries.

When soil tests are done and recommendations come out, every soil is probably going to give you a slightly different response curve to the crop of interest. You can't develop response curves for every soil type in any given state, so some generalizations have to be made. The truth of the matter is these response curves have not been developed for strawberries, raspberries, and blueberries on all different soil types. Oftentimes agronomists have generated these curves for field crops, but not so much for berry crops, so educated guesses need to be made on how berry crops will respond. One approach is to find an agronomic crop that has a similar response to a berry crop and use that as a guide; for example, strawberries/raspberries mimic alfalfa so alfalfa guidelines can be used as a basis for a recommendation as these three crops have the same rooting depth, pH requirements, and are all perennial.

Researchers have generated nutrient response curves for some berry crops, but there just aren't many available to use for calibration. Below is an example of a response curve for nitrogen in strawberries (*Figure 3*). Fertilizer was applied in a liquid form so it's not easily converted to pounds per acre, but the point is at low N levels, not much response occurs, and while more response is seen as N increases, the rate of increase diminishes. Leaf area increases with increasing N (277% between 10N and 20N); but yield is not nearly as responsive to increasing N (increasing only 22% when N is doubled); the optimal rate is about 10 N or equivalent to about 100 lbs/A year.

**Figure 3.** Response of strawberries to increasing amounts of nitrogen fertilizer.

	0 N	5 N	10 N	15 N	20 N
Leaf Area(cm <sup>2</sup> )	627.2	1725.2	2493.9	3003.7	3903.4
Crown (g)	13.4	29.4	39.8	44.6	45.6
Runner (g)	4.1	6.5	22.0	31.1	39.1
Roots (g)	7.6	20.4	31.3	41.4	59.0
Yield (g)	97.0	166.9	172.7	214.7	210.8

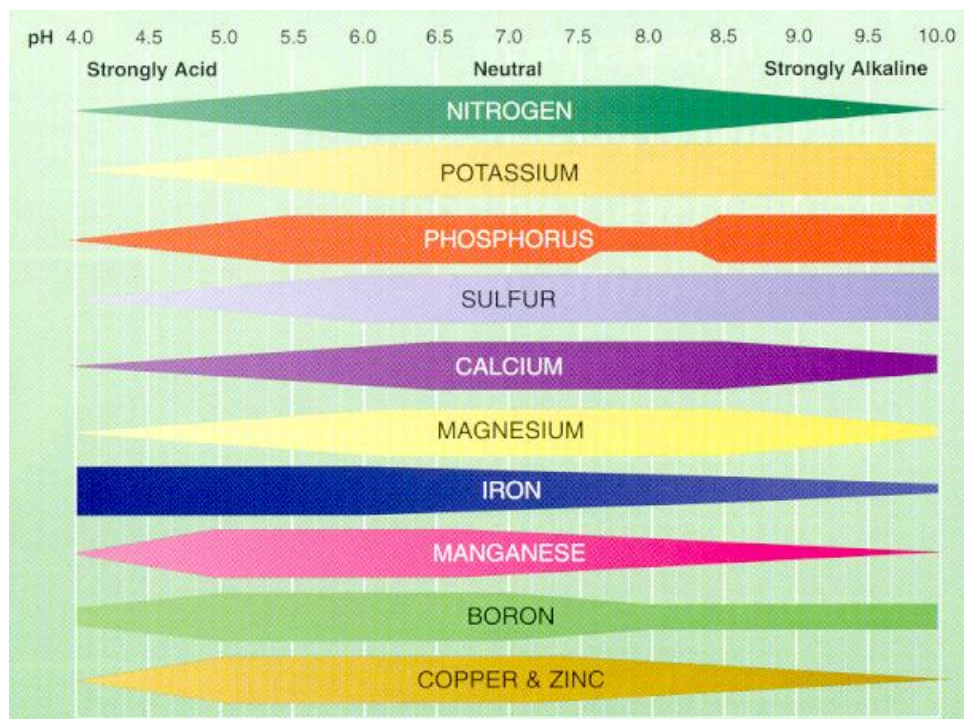
Optimal Rate

Some recommendations are based on response curves that are dependent on soil type (e.g. Morgan extractant). Others are less dependent on soil type (modified Morgan) mostly due to the differences in the amount of potassium extracted. You have to assume test results are good and accurate and that the recommendations are on target. Recommendations should be mostly the same whether one is organic or conventional; the difference lies in the sources of the fertilizer/amendment used – not in the recommended amount of nutrient needed. So, for example, the recommendation might be for 50 lb potassium regardless of growing method. The source of that potassium applied for the organic vs the conventional grower may differ, however. There are a few exceptions to this depending on release rate; some organic amendments have slower release rates so higher amounts may be indicated.

The most important adjustment we usually make is to soil pH. If pH is not within a desired range, then the ability of the plant to take up nutrients will be compromised (*Figure 4*). If pH is not right you can apply a lot of a particular nutrient to soil but it will not be available to the plant because of the pH. The amount of nutrient available to the plant is very dependent on soil pH. (*Right: iron deficiency in blueberry, photo courtesy M. Pritts*) The optimal soil pH range for most crops is 6.0 to 6.5; at this range most of the nutrients are readily available. The exception to this rule is blueberries where the optimum is down around 4.5.



**Figure 4.** Availability of soil nutrients in relation to pH.



### Adjusting soil pH

Changing the pH after planting is very slow and difficult. Sulfur or lime to adjust pH is best applied preplant in order to work it down into soil adequately (*Figures 5a and 5b*).

**Figures 5a and 5b.** Post plant application of lime to strawberries (left) and raspberries (right). Photos courtesy M. Pritts. NOTE: This is not a recommended practice.



Sulfur can be used to lower pH and lime can be used to raise pH. Aluminum sulfate is often recommended in catalogs for lowering pH. Aluminum sulfate does provide a rapid change of pH, but excess aluminum is toxic to plants, so it is not the best choice.



The amount of lime to apply is dependent on: 1) The difference between current pH and target pH (how big is the gap between where you want to be and where you are) and 2) cation exchange capacity (CEC) or soil buffering capacity. CEC is the ability of the soil to hold onto cations in the soil through exchange sites (negative charges on soil particles), and it is the ratio of the cations to these exchange sites that determine pH (cation/hydrogen ion ratio). This ratio is often called “base saturation” or the percent of the exchange sites occupied by bases. Bases include Ca<sup>++</sup>, Mg<sup>++</sup> and K<sup>+</sup> these are the most important. Exchange sites not occupied by cations are populated by Hydrogen ions (H<sup>+</sup>). The higher the ratio of hydrogen ions to cations, the more acid the soil is. The greater the number of hydrogen ions you need to knock off the exchange sites, the more base (Ca and Mg) will be needed to do so.

Exchange sites are comprised of negatively-charged clay particles and organic matter that hold onto the positively charged cations. Soils that are high in CEC require more sulfur or lime to change the pH, but once adjusted, are more stable. The reverse is also true, soils low in CEC are easier to adjust but revert back to low pH as the Ca and Mg ions leach from soil and are replaced with hydrogen ions, dropping the pH again. To reiterate: It’s easy to raise pH of sandy soil with low OM (low CEC). It is hard to lower pH of clayey soil having higher OM content as clay and OM contribute to negative charges in soil.

**Table 1.** Amount of sulfur (lb/A) required to lower pH to a desired level of 4.5 for blueberries.

Current pH	Sand	Loam	Clay
5.0	175	530	5800
5.5	350	1000	1600
6.0	660	1880	3030
6.5	1250	3560	5730

The amount of sulfur to lower pH to a desired level of 4.5 depends on the current pH and the soil type (*Table 1*). The further from target pH of 4.5, the more sulfur is needed to lower pH, and the higher the CEC capacity of soil, the more sulfur is needed to lower pH. It is extremely difficult to lower pH for alkaline (high pH) soils with a high CEC as extremely large amounts of sulfur are required. The initial sulfur expense, coupled with the need for additional sulfur on a biannual basis to reach/maintain lower pH makes this prohibitive. For this reason these soils are often deemed unsuitable for blueberry production.

Soil tests attempt to estimate the amount of lime (or sulfur) required to bring the pH to within the desired range for a particular crop based on cation exchange capacity, CEC (*Table 2*). Soil tests do not measure CEC directly; they do not measure the number of negative charges present, or the number of these populated by hydrogen ions. They use indirect methods to estimate the amount of hydrogen ions on the exchange complex. One would suppose lime recommendations would be extremely precise, but most often they are an estimate, putting you within the ballpark. The reasons for this are 3-fold: estimating CEC is an inexact science, different procedures are used among labs, and CEC varies with pH and other factors.

**Table 2.** Cation exchange capacity (CEC) of various soils.

Material	CEC (cation exchange capacity)
Sands	2 – 10
Loams	7 – 25
Clays	20 – 40
Humus (organic matter)	200 - 400

Adding lime or sulfur to the soil does not change the pH instantly. Significant time is required for lime or sulfur to affect pH (6 months or longer). The rate of pH change is affected by the particle size of the lime or sulfur (smaller, quicker, larger slower), soil moisture (dry soils, slower, moist soils, faster), temperature (slower in winter, faster in spring, summer, fall), and good aeration as oxygen is needed for the biological process of pH change to happen.

## Interpreting soil test results

Results (and reports) vary from lab to lab. Below is a sample strawberry soil test report from the Agro-One lab in Ithaca, NY, which will be used to highlight things to note when reviewing soil test results and recommendations.

### Checklist: Things to look for when interpreting soil test results for berry crops

- ✓ **Soil pH.** The desired pH for strawberries 6.0 to 6.8 (this sample is in that range...). Check the fertilizer recommendations at the bottom of the report; in this instance, no lime or sulfur is suggested as the pH is acceptable at 6.1. Note buffer pH is also listed. Buffer pH is used to estimate CEC; greater the difference between pH and buffer pH, the greater the CEC capacity, and the more difficult to modify the pH.

Component		Mod. Morgan ppm	Mod. Morgan lbs/acre	Morgan Equiv. lbs/acre	Soil Test Levels					
					Very Low	Low	Medium	High	Very High	
Phosphorus (P)		4	8	9	*****					
Potassium (K)		88	176	175	*****					
Calcium (Ca)		1,802	3,605		*****					
Magnesium (Mg)		302	603		*****					
Water		Calcium Chloride		No Till		Organic Matter (%)	Nitrate-N (ppm)	HWS Boron (lbs/acre)	Soluble Salts (mmhos/cm)	Total N (%)
pH	Buffer pH	pH	Buffer pH	pH	Buffer pH					
6.1	5.9					4.6		0.9		
Other Nutrients, Mod. Morgan, lbs/acre										
Sodium (Na)		Aluminum (Al)		Sulfur (S)	Zinc (Zn)	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Boron (B)	Molybdenum (Mo)
		62.6			0.5	14.6	5.6			
Soil Fertilizer Recommendations		tons / acre		lbs / acre			lbs / 1000 sqft			
Year	Crop	Lime		N	P2O5	K2O	Lime	N	P2O5	K2O
1	Strawberries, Spring	0.0		100	25	0	0.0	2.3	0.6	0.0
Comments										
Nutrient recommendations provided by Cornell University. These are general comments. Always consult with your crop advisor for recommendations specific to your farm. For assistance interpreting your report, contact your local Cooperative Extension office at 607-272-2292. Yr1 Apply 80 lbs/acre of N in July, and another 20 lbs/acre the first of September. Do not apply N in early spring except on sandy soils. Yr1 Apply fertilizer uniformly around the plants or through drip irrigation. Do not allow granules to remain on leaves. Do not fertilize when leaves are wet. Yr1 The best time to apply potassium and phosphorus fertilizers is in the fall before mulch is applied. Yr1 Use both a soil test and leaf analysis to adjust nutrient levels.										

- ✓ **Organic matter content** - 2% or higher most desirable for berry crops; OM. If OM is 2% or less, cover crops or compost applications should be implemented to boost OM prior to planting.

Component	Mod. Morgan ppm	Mod. Morgan lbs/acre	Morgan Equiv. lbs/acre	Soil Test Levels				
				Very Low	Low	Medium	High	Very High
Phosphorus (P)	4	8	9	*****	*****	*****	*****	*****
Potassium (K)	88	176	175	*****	*****	*****	*****	*****
Calcium (Ca)	1,802	3,605		*****	*****	*****	*****	*****
Magnesium (Mg)	302	603		*****	*****	*****	*****	*****
Water		Calcium Chloride		No Till		Organic Matter (%)	Nitrate-N (ppm)	HWS Boron (lbs/acre)
pH	Buffer pH	pH	Buffer pH	pH	Buffer pH			
6.1	5.9					4.6		0.9
Other Nutrients, Mod. Morgan, lbs/acre								
Sodium (Na)	Aluminum (Al)	Sulfur (S)	Zinc (Zn)	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Boron (B)	Molybdenum (Mo)
	62.6		0.5	14.6	5.6			
Soil Fertilizer Recommendations		tons / acre	lbs / acre			lbs / 1000 sqft		
Year	Crop	Lime	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Lime	N	P <sub>2</sub> O <sub>5</sub>
1	Strawberries, Spring	0.0	100	25	0	0.0	2.3	0.6
								0.0
Comments								
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- ✓ **Macronutrient levels** (P, K, Ca, and Mg). These are generally reported in either parts per million (PPM) or pounds per acre (lb/A). PPM x 2 equals pounds per acre so it is easy to convert between the two values. The columns to the right of lbs/acre indicate the relative levels of soil nutrients, which vary by soil type and crop being grown. “High” is considered a sufficient level and may not generate a fertilizer recommendation. “Medium” is considered adequate for the short term but may generate a recommendation to maintain and/or build levels for the future, as in the case of phosphorus in the report below. (Other macronutrient components displayed in Appendix C).
- ✓ **Soil fertilizer recommendations:** Note the recommendation of 25 pounds per acre refers to pounds of actual nutrient, not pounds of fertilizer. For example, an N-P-K fertilizer such as 10-10-10 is only 10% P<sub>2</sub>O<sub>5</sub> by weight, so to apply 25 lb P you would need 25/0.1 or 250 lbs of fertilizer. Note at the same time you would also be applying 25 lb/ac of N and K. To avoid over applying potassium which you already have in sufficient supply consider using a fertilizer like Monoammonium phosphate (MAP) 11-52-0 which is 11% N, 52% P<sub>2</sub>O<sub>5</sub> and no K. (Further fertilizer recommendations in Appendix C).

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Calcium (Ca)			1,802	3,605		*****	*****	*****					
Magnesium (Mg)			302	603		*****	*****	*****					
Water		Calcium Chloride		No Till		Organic Matter (%)	Nitrate-N (ppm)	HWS Boron (lbs/acre)	Soluble Salts (mmhos/cm)	Total N (%)			
pH	Buffer pH	pH	Buffer pH	pH	Buffer pH								
6.1	5.9					4.6		0.9					
Other Nutrients, Mod. Morgan, lbs/acre													
Sodium (Na)		Aluminum (Al)		Sulfur (S)		Zinc (Zn)		Manganese (Mn)		Iron (Fe)	Copper (Cu)	Boron (B)	Molybdenum (Mo)
		62.6				0.5		14.6		5.6			
Soil Fertilizer Recommendations				tons / acre		lbs / acre			lbs / 1000 sqft				
Year	Crop			Lime		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Lime	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	
1	Strawberries, Spring			0.0		100	25	0	0.0	2.3	0.6	0.0	
Comments													
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- ✓ **Nitrogen:** Nitrogen is not usually reported in soil test results as the amount in soil at any given time changes rapidly due to cycling between the various forms of N (NO<sub>3</sub>, NO<sub>2</sub>, NH<sub>4</sub>, and organic N), weather changes, and leaching. Thus, the nitrogen recommendation in this report is based on annual strawberry crop requirements for N rather than soil test results. Use foliar nitrogen test results to adjust this rate accordingly (see Appendix C).

						Soil Test Levels				
Component		Mod. Morgan ppm	Mod. Morgan lbs/acre	Morgan Equiv. lbs/acre		Very Low	Low	Medium	High	Very High
Phosphorus (P)		4	8	9		*****				
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Water		Calcium Chloride		No Till		Organic Matter (%)	Nitrate-N (ppm)	HWS Boron (lbs/acre)	Soluble Salts (mmhos/cm)	Total N (%)
pH	Buffer pH	pH	Buffer pH	pH	Buffer pH					
6.1	5.9					4.6		0.9		
Other Nutrients, Mod. Morgan, lbs/acre										
Sodium (Na)	Aluminum (Al)	Sulfur (S)	Zinc (Zn)	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Boron (B)	Molybdenum (Mo)		
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- ✓ **Micronutrient levels** (ICP analysis): Aluminum, zinc, manganese, and iron values are reported here; these levels are not generally used for recommendations as foliar analysis a better indicator of the status of these micronutrients. Thus it is good to review both soil and leaf analysis results together. When test results indicate micronutrients are present in soil but foliar tests indicate deficiencies, it may indicate either pH is not in the desired range, or other root issues exist that are affecting micronutrient uptake. That said these values may require some consideration in evaluating possible toxicities. One example of this is aluminum; soil aluminum levels above 300 PPM are considered toxic to blueberries. The same levels are not necessarily toxic to strawberries and raspberries, as the higher the pH the less available aluminum becomes in soil (Appendix D).

Mod. Morgan						Mod. Morgan		Morgan Equiv.		Soil Test Levels																	
Component		ppm		lbs/acre		lbs/acre				Very Low		Low		Medium		High		Very High									
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pH	Buffer pH	pH	Buffer pH	pH	Buffer pH																						
6.1	5.9						4.6				0.9																
Other Nutrients, Mod. Morgan, lbs/acre																											
Sodium (Na)		Aluminum (Al)		Sulfur (S)		Zinc (Zn)		Manganese (Mn)		Iron (Fe)		Copper (Cu)		Boron (B)		Molybdenum (Mo)											
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Note that boron is not reported on this test. Boron may also have impact on plant growth; particularly in strawberries and raspberries; in this case it is more likely to be a deficiency rather than an excess as with aluminum. Request boron testing if it is not included in the standard soil test you are using. Recommended boron levels may vary slightly from lab to lab but in general boron levels of < 0.35 PPM (multiply by 2 for lb/A) are considered low for berry crops; soils with 0.35 to 0.75 PPM are considered medium and soils with > 0.75 PPM are considered high.

Soil boron is very prone to leaching, especially in soils with low organic matter content, so it is one of the most commonly observed micronutrient deficiencies in berry plantings. Boron deficiencies lead to poor root growth (*Figure 6*), which in turn causes deficiencies of other nutrients due to poor uptake. This sometimes manifests itself when leaf analyses indicate micronutrient deficiencies, even though the soil pH is in range and soil test results indicate sufficient levels of the nutrient(s). Note that poor root growth from other causes may have the same effect. Boron is also important in fruit set. Boron is highly mobile in soil and may be applied any time of year, making a boron deficiency fairly easy to correct. If boron is required apply no more than 2 lb actual boron/A (i.e. 10lb/A Solubor) in any one year.

**Figure 6.** Comparison of strawberry roots grown in complete nutrient solution including boron (left) and nutrient solution minus boron (right). Note sparse, stubby roots of boron deficient plant. Photos courtesy: M. Pritts.



- ✓ **Comments:** This section contains nutrient recommendations as well as information on application methods, timing and other relevant information.

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pH	Buffer pH	pH	Buffer pH	pH	Buffer pH								
6.1	5.9					4.6		0.9					
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Sodium (Na)		Aluminum (Al)		Sulfur (S)		Zinc (Zn)		Manganese (Mn)		Iron (Fe)	Copper (Cu)	Boron (B)	Molybdenum (Mo)
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Yr1 Use both a soil test and leaf analysis to adjust nutrient levels.													

You must have confidence in recommendations provided by your lab. The best analysis in the world is useless without a good recommendation; many analytical labs provide “general plant recommendations for field crops” without fine-tuning to the needs of specific crops i.e. a blueberry recommendation that looks like one for corn.

**Appendix B** provides conversion factors for determining fertilizer application rates for fields smaller than one acre for various berry crops. **Appendices C through E** provide nutrient concentrations for various fertilizers.

## Test Your Skills – Interpreting Berry Soil Test Results

What follows are seven examples of soil test results, summarized in tabular form for ease of reading. Test your skills by reviewing the soil test results checklist for each report, then make a recommendation based on your observations. Answers/recommendations follow in the box at the bottom of each page.

### *Exercise 1: Strawberries, Clay Loam Soil*

Nutrient	Soil (lb/A)
Nitrogen (N)	-----
Phosphorus (P)	Medium
Potassium (K)	High
Calcium (Ca)	High
Magnesium (Mg)	Low
Manganese (Mn)	
Iron (Fe)	
Copper (Cu)	
Boron (B)	1.5
Zinc (Zn)	
pH	5.2
Organic Matter	5.3%

Your checklist:

- ✓ pH: \_\_\_\_\_
- ✓ Organic Matter: \_\_\_\_\_
- ✓ Macronutrients (P, K, Ca, Mg): \_\_\_\_\_
- ✓ Micronutrients: \_\_\_\_\_

Your Recommendation(s): \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Checklist:** pH should be 6.0 to 6.5 for strawberries. Phosphorus is a little low; also magnesium low; step, plus phosphorus.  
**Recommendation:** Lime to raise pH; apply high magnesium (dolomitic) lime to correct both pH and Mg in one

### Exercise 2: Blueberries, Sandy Loam Soil

Nutrient	Soil (lb/A)
Nitrogen (N)	-----
Phosphorus (P)	High
Potassium (K)	High
Calcium (Ca)	Low
Magnesium (Mg)	High
Manganese (Mn)	
Iron (Fe)	
Copper (Cu)	
Boron (B)	1.5
Zinc (Zn)	
pH	4.8
Organic Matter	5.3%

Your checklist:

- ✓ pH: \_\_\_\_\_
- ✓ Organic Matter: \_\_\_\_\_
- ✓ Macronutrients (P, K, Ca, Mg): \_\_\_\_\_
- ✓ Micronutrients: \_\_\_\_\_

Your Recommendation(s): \_\_\_\_\_

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**Answer:** pH ok; others OK, Calcium is low – what to do as the pH ok? **Recommendation:** Gypsum or Calcium sulfate to increase calcium; these forms do not affect pH.

### Exercise 3: Raspberries, Loamy Soil

Nutrient	Soil (lb/A)
Nitrogen (N)	-----
Phosphorus (P)	High (15)
Potassium (K)	High (140)
Calcium (Ca)	High (4,367)
Magnesium (Mg)	High (409)
Manganese (Mn)	
Iron (Fe)	
Copper (Cu)	
Boron (B)	
Zinc (Zn)	
pH	6.2
Organic Matter	5.3%

Your checklist:

- ✓ pH: \_\_\_\_\_
- ✓ Organic Matter: \_\_\_\_\_
- ✓ Macronutrients (P, K, Ca, Mg): \_\_\_\_\_
- ✓ Micronutrients: \_\_\_\_\_

Your Recommendation(s): \_\_\_\_\_

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**Answer:** Levels seem ok – would soil test recommend anything here? Recommendation: High levels of one cation (Ca) can suppress uptake of the other two...Ca/Mg ratio higher than 100; typical ratio in soil is 5.  
**Recommendation:** Apply magnesium sulfate to add small amount of Mg to soil to balance ratio.



#### Exercise 4: Blueberries, Sandy Loam Soil

Nutrient	Soil (lb/A)
Nitrogen (N)	-----
Phosphorus (P)	Low
Potassium (K)	High
Calcium (Ca)	Medium
Magnesium (Mg)	Medium
Manganese (Mn)	
Iron (Fe)	
Copper (Cu)	
Boron (B)	2.0
Zinc (Zn)	
pH	5.9
Organic Matter	1.3%

Your checklist:

- ✓ pH: \_\_\_\_\_
- ✓ Organic Matter: \_\_\_\_\_
- ✓ Macronutrients (P, K, Ca, Mg): \_\_\_\_\_
- ✓ Micronutrients: \_\_\_\_\_

Your Recommendation(s): \_\_\_\_\_

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**Checklist:** pH 5.9 out of range for blueberries (4.2 to 4.5); organic matter low (< 2.0); P and K low; Mg slightly low. **Recommendation:** Lower pH, increase organic matter; other values may fall in line once this is done so no other recommendations apart from that at the moment.

**Exercise 5: Blueberries, Clay Loam Soil, (preplant)**

Nutrient	Soil (lb/A)
Nitrogen (N)	-----
Phosphorus (P)	Medium
Potassium (K)	High
Calcium (Ca)	High
Magnesium (Mg)	High
Manganese (Mn)	
Iron (Fe)	
Copper (Cu)	
Boron (B)	2.0
Zinc (Zn)	
pH	5.9
Organic Matter	4.3%

**Your checklist:**

- ✓ pH: \_\_\_\_\_
- ✓ Organic Matter: \_\_\_\_\_
- ✓ Macronutrients (P, K, Ca, Mg): \_\_\_\_\_
- ✓ Micronutrients: \_\_\_\_\_

**Your Recommendation(s):** \_\_\_\_\_

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**Checklist:** CEC high, pH and OM high, already high in Ca, Mg. **Recommendation:** Don't Grow Blueberries! This is not a suitable blueberry soil; select another site.

### Exercise 6: Strawberries, Sandy Soil

Nutrient	Soil (lb/A)
Nitrogen (N)	-----
Phosphorus (P)	Medium
Potassium (K)	High
Calcium (Ca)	Low
Magnesium (Mg)	Medium
Manganese (Mn)	
Iron (Fe)	
Copper (Cu)	
Boron (B)	0.5
Zinc (Zn)	
pH	5.6
Organic Matter	1.1%

Your checklist:

- ✓ pH: \_\_\_\_\_
- ✓ Organic Matter: \_\_\_\_\_
- ✓ Macronutrients (P, K, Ca, Mg): \_\_\_\_\_
- ✓ Micronutrients: \_\_\_\_\_

Your Recommendation(s): \_\_\_\_\_

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**Checklist:** Low pH, low organic matter, low Ca, Low P, Low Bo. **Recommendations:** Add Calclitic lime to raise pH, add Ca. Add Phosphorus, Boron, Organic matter.

### Exercise 7: Raspberries, Loamy Soil

Nutrient	Soil (lb/A)
Nitrogen (N)	-----
Phosphorus (P)	Medium
Potassium (K)	Medium
Calcium (Ca)	Medium
Magnesium (Mg)	Medium
Manganese (Mn)	
Iron (Fe)	
Aluminum (Al)	389
Boron (B)	2.2
Zinc (Zn)	
pH	6.2
Organic Matter	4.9%

Your checklist:

- ✓ pH: \_\_\_\_\_
- ✓ Organic Matter: \_\_\_\_\_
- ✓ Macronutrients (P, K, Ca, Mg): \_\_\_\_\_
- ✓ Micronutrients: \_\_\_\_\_

Your Recommendation(s): \_\_\_\_\_

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**Checklist:** pH, OM ok; macronutrients medium range; aluminum level pretty high. **Recommendation:** Add a small amount P and K; add a slightly higher amount lime than recommended to push pH to high end to make aluminum less available.

### A real life example: blueberries



*Foreground: blueberry bushes not growing very well, grass mostly dead. Background: bushes performing better, some grass in row middles. What is happening here? Three soil tests were taken in three different age plantings. Photo courtesy C. Heidenreich.*

#### **Test Results/Observations:**

**1994:** soil pH 4.7, Al 170, P 4 lb/A—healthy plants, living sod

**2001:** soil pH 5.2, Al 552, P 6 lb/A—sick plants, dead sod

**2003:** soil pH 6.6, Al 670, P 12 lb/A—fair plants, living sod

The plants at the higher pH were better off than plants at a lower pH. Why? Aluminum levels in that soil were very high but the aluminum was less available at the higher pH. At the lower pH site, aluminum was more available, hence the toxicity symptoms seen here... Bottom line: This is not a good site for growing blueberries (or any berry crop) because of the inherently high aluminum levels.

### **Nutrient uptake**

Nutrient uptake in soil occurs in 3 different ways: 1) Direct contact with roots, 2) mass flow (water soluble, through transpirational stream) and/or 3) diffusion (short distance transport in water, from higher concentration in soil to lower concentration in the root (*Table 3*).

Nutrients are primarily taken up by contact and diffusion and must be in close proximity to the root itself. Since on average 1% and at most 3% of the soil surface is in direct contact with the root surface, nutrients must be



thoroughly incorporated in to soil prior to planting for good uptake. Table 3 gives modes of uptake for various nutrients in corn; these modes are appropriate for most crops.

**Table 3:** *Modes of uptake (% though each mechanism) for various nutrients in corn.*

Nutrient	Root interception	Mass flow	Diffusion
<b>Nitrogen (N)</b>	1	99	0
<b>Phosphorus (P)</b>	3	6	94
<b>Potassium (K)</b>	2	20	78
<b>Calcium (Ca)</b>	28	72	0
<b>Magnesium (Mg)</b>	13	87	0
<b>Copper (Cu)</b>	3	97	0
<b>Zinc (Zn)</b>	33	33	33
<b>Boron (B)</b>	3	97	0
<b>Iron (Fe)</b>	11	53	37
<b>Manganese (Mn)</b>	20	80	0
<b>Molybdenum (Mo)</b>	5	95	0

Note: nitrogen is mostly taken up by mass flow. Nitrogen (in the nitrate or ammonium forms) gets dissolved in aqueous solution in soil which moves into the root system as the plant transpires; water transpires through the leaf leaving the nitrogen inside the plant. Thus nitrogen may be applied to the soil surface, dissolves and gets to the roots of the plant even after the plant is established. Boron is also very highly soluble and is taken up by mass flow as well.

Other nutrients, such as phosphorus and potassium are taken up by diffusion; they do not rapidly dissolve or move through the soil very quickly, thus they must be well-incorporated in soil.

Once plants are established, a foliar analysis will provide many more clues to help diagnose nutrient problems.

## Summary

The goal of soil testing is to estimate the plant-available nutrient levels in soil. Ensuing test results are accompanied by recommended levels of amendments to bring up levels to some optimum for the berry crop of choice.

The most important adjustment to make is soil pH. If pH is not within a desired range, then the ability of the plant to take up nutrients will be compromised. The optimal soil pH range for most crops is between 6.0 to 6.5; at this range most of the nutrients are readily available. The exception to this rule is blueberries where the optimum is 4.5.

Adding lime or sulfur to the soil does not change the pH instantly. Significant time is required for lime or sulfur to affect pH (6 months or longer). The rate of pH change is affected by particle size (smaller-quicker, larger-slower), soil moisture (dry soils- slower, moist soils-faster), temperature (slower in winter, faster in spring, summer, fall), and good aeration as oxygen is needed for the biological process of pH change to happen.

Things to look for when interpreting soil test results include soil pH, organic matter content, macro nutrients (P, K, Ca, Mg), and micronutrients (to a lesser degree). Boron is one of the most commonly observed micronutrient deficiencies in berry plantings. High aluminum levels in soil are often the cause of phytotoxicity at lower pH levels.

Nutrient uptake in soil occurs in 3 different ways: 1) Direct contact with roots, 2) mass flow (water soluble, through transpirational stream) and/or 3) diffusion (short distance transport in water, from higher concentration in soil to lower concentration in the root. Those nutrients such as nitrogen and boron that are taken up directly or by mass flow may be applied to the soil surface. Nutrients taken up primarily by diffusion such as P, K, Ca, and Mg are best mixed thoroughly into soil before planting and rarely need to be applied subsequent to planting.

## **Additional Resources**

1. *Understanding Your Agro-One Soil Test Results*  
<http://www.fruit.cornell.edu/berry/production/pdfs/UnderstandingAgro1results.pdf>
2. *Leaf and soil tests on local berry farms: Lessons from summer 2010*  
<http://www.fruit.cornell.edu/berry/production/pdfs/berrysoilleaftestshaw.pdf>